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Regulatory Analysis for the Noise Emission Regulations for Motorcycles and Motorcycle Exhaust Systems

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This document presents the technical data and analyses used by EPA in developing the noise emission regulations for motorcycles and motorcycle exhaust systems. The information presented includes a detailed discussion of: the motorcycle and motorcycle exhaust systems industry; baseline noise levels for current motorcycles; the noise control technology available; the adverse health and welfare impacts of motorcycle noise and the potential benefits of regulation; the expected costs and potential economic effects of regulation; and the noise measurement methodology.

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Noise

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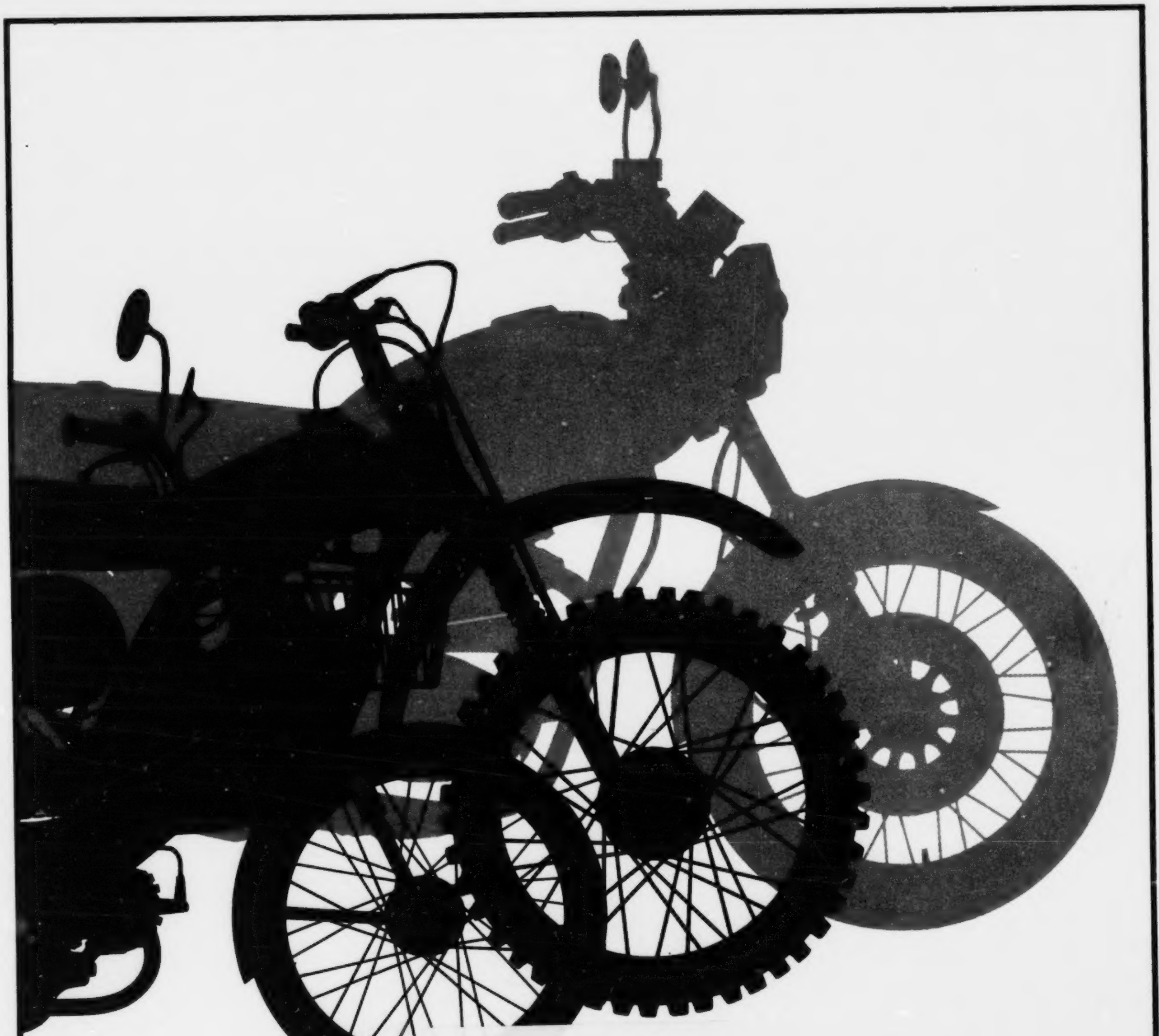

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REGULATORY ANALYSIS
FOR THE NOISE EMISSION REGULATIONS
FOR MOTORCYCLES AND MOTORCYCLE EXHAUST SYSTEMS

December 1980

U.S. Environmental Protection Agency
Office of Noise Abatement and Control
Washington, D.C. 20460

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SECTION 1

INTRODUCTION

SECTION 1

INTRODUCTION

Statutory Basis for Action

Through the Noise Control Act of 1972 (86 Stat. 1234), Congress established a national policy "to promote an environment for all Americans free from noise that jeopardizes their health and welfare." In pursuit of that policy, Congress stated in Section 2 of the Act that "while primary responsibility for control of noise rests with State and local governments, Federal action is essential to deal with major noise sources in commerce, the control of which requires national uniformity of treatment." As part of that essential Federal action, subsection 5(b)(1) requires the Administrator of the Environmental Protection Agency (EPA), after consultation with appropriate Federal agencies, to publish a report or series of reports identifying products (or classes of products) which in his judgment are major sources of noise. Further, Section 6 of the Act requires the Administrator to publish proposed regulations for each product identified as a major source of noise and for which, in his judgment, noise standards are feasible. Such products fall into various categories, of which transportation equipment (including recreational vehicles and related equipment) is one.

Identification of Motorcycles as a Major Noise Source

Pursuant to the provisions of subsection 5(b)(1), the Administrator on May 20, 1975 published a report identifying new motorcycles as a major source of noise.[1] Section 6 requires EPA to prescribe standards for the noise emissions of new motorcycles which are requisite to protect the public health and welfare, taking into account the magnitude and conditions of use of new motorcycles, the degree of noise reduction achievable through the application of best available technology, and the cost of compliance.

In accordance with the authorities granted in Sections 3, 6, and 10 of the Act, EPA may establish performance standards for specific components of those products which have been identified as major sources of noise. Replacement exhaust systems, which are noise sensitive components of motorcycles, have, in the judgment of the Administrator, been found to warrant separate regulatory treatment as part of EPA's noise abatement strategy for new motorcycles.

Labeling

Provisions for requiring the labeling of products identified as major sources of noise are contained in Sections 6 and 13 of the Noise Control Act. Labeling of motorcycles will provide notice to buyers that the product is sold in conformity with applicable regulations, and will also make the buyer and user aware that the motorcycle possesses noise attenuation devices which should not be removed or tampered with. Labeling will also be of assistance to enforcement officials in determining compliance with applicable laws and ordinances.

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[1] Federal Register; 40 FR 23105, May 28, 1975

Preemption

After the effective date of a regulation for noise emissions from a new product, Section 6 of the Noise Control Act requires that no State or political subdivision thereof may adopt or enforce any law or regulation which sets a limit on noise emissions from such new products, or components of such new products, which is not identical to the standard prescribed by the Federal regulation. Subsection 6(e)(2), however, provides that nothing in Section 6 precludes or denies the right of any State or political subdivision thereof to establish and enforce controls on environmental noise through the licensing or the regulation or restriction of the use, operation, or movement of any such product or combination of products.

To assist in controlling motorcycle noise, State and local authorities are encouraged to enact and enforce noise regulations for motorcycles and replacement exhaust systems which complement Federal regulations, as well as regulations controlling the use and operation of motorcycles in areas where they are deemed to be necessary.

Study Approach

In June 1974 EPA published a preliminary study report which examined motorcycle quieting technology and the costs of applying such technology.[2] This study provided the Agency with an initial assessment of the feasibility of motorcycle noise control, from which the Agency's regulatory options could be further considered. Shortly after the major noise source identification of motorcycles by the Administrator, EPA initiated further research studies of quieting technology, cost and economic impacts, and environmental impacts, to be used in assessing the various Federal noise regulatory alternatives for this product.

During the course of these studies, all major motorcycle manufacturers, many smaller ones, and a number of manufacturers of replacement exhaust systems were visited by representatives of the Agency and its contractors. These visits were made for the purposes of collecting technical data and information, and to allow the industry the opportunity to become familiar with and participate in EPA's regulatory process.

Information and data collected from various sources by EPA and its contractors which were used by the Agency in assessing motorcycle quieting technology, compliance costs, and health and welfare impacts are presented in this document.

Public Participation

Throughout the development of this regulation an effort has been made to allow all groups and organizations who have an interest in, or may be directly affected by motorcycle noise standards, the opportunity to participate in the rulemaking process. This public participation effort has included meetings with concerned state, county, and city officials, as well as with motorcycle user groups, industry associations, and motorcycle dealers. Advance copies of a draft Notice of Proposed Rulemaking (NPRM) and selected sections of the

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Control of Motorcycle Noise, Volume I, Techonology and Cost Information. EPA publication 550/9-74-001A supporting regulatory analysis were distributed to manufacturers and interested government officials several months prior to publication of the NPRM to allow additional time for analysis and comment. Appropriate officials in all 50 states were contacted by telephone, and informational mailings were sent and follow-up contacts made for the purpose of obtaining viewpoints and opinions from these officials. Ongoing attempts to coordinate Federal, state, and local motorcycle noise control actions are being made by the Agency.

On March 15, 1978 a Notice of Proposed Rulemaking for Motorcycles and Motorcycle Replacement Exhaust Systems was published in the Federal Register (40 FR 10822). Public hearings were held in Anaheim, California, April 28 - May 1, 1978; in St. Peterburg, Florida, May 5, 1978; and in Washington, D.C., May 9, 1978. All comments submitted with respect to the proposed regulation during the public hearings and during the public comment period have been given careful consideration. An analysis of these comments is included in this document.

Outline and Summary of the Background Document and Appendices

Section 1. Introduction

Section 2. Industry Description. General information on motorcycles, motorcycle manufacturers, exhaust system manufacturers, and the structure of the industry is presented in this section.

Section 3. Noise Level Test Procedures. This section contains a discussion of existing noise measurement methodologies for motorcycles, and a presentation of EPA's final procedure for use in regulatory compliance testing.

Section 4. Noise Level Data Base. This section presents noise levels of motorcycles and replacement exhaust systems which were obtained using various test procedures.

Section 5. Public Health and Welfare Analysis. An analysis of current impacts of motorcycle noise, and impacts expected as a result of various regulatory options is described.

Section 6. Noise Reduction Technology. A discussion of motorcycle noise reduction feasability is included in the section. In addition the various engineering techniques involved in controlling noise from motorcycle noise subsources are also analyzed.

Section 7. Costs of Compliance. This section provides estimates of the costs involved in applying these techniques to quiet motorcycles and replacement exhaust systems to various not-to-exceed regulatory levels.

Section 8. Economic Impact Analysis. Estimates of the economic impacts of various regulatory options on the manufacturing industry, on specific firms, on employment and on other economic measures are contained in this section.

Appendix A. Motorcycle Noise Level Test Procedures. Texts of the noise level test procedures discussed in Section 3 are presented in this appendix.

Appendix B. Test Sites and Instrumentation. This appendix presents descriptions and photographs of the instrumentation and the test site locations used in performing EPA's motorcylce noise testing.

Appendix C. Product Identification and Noise Levels. This appendix includes noise level data developed by EPA on individual motorcycles and replacement exhaust systems.

Appendix D. A synopsis of State and local laws applicable to motorcycle noise.

Appendix E. This appendix includes a summary of foreign motorcycle noise laws.

Appendix F. Motorcycle and Aftermarket Exhaust System Demand Forecasting Model. This appendix describes the econometric models used to forecast motorcycle and aftermarket exhaust system demand.

Appendix G. Relation Between Standard Test Methodologies and Representative Acceleration Conditions. The assessed relationship between motorcycle noise levels under rapid acceleration conditions (the official EPA test procedure) and noise levels under representative unconstrained traffic acceleration conditions is detailed in this appendix.

Appendix H. Additional Motorcycle Noise Level Data. This appendix contains data developed in a test program conducted by EPA to gain additional data relating to the proposed test procedure and to investigate tachometer response characteristics. Operator ear and stationary test data are also presented.

Appendix I. This appendix describes results of EPA's efforts to develop a sliding scale of closing RPM so that more accurate comparisons could be made between the noise levels of various motorcycles displacement classes. Also tachometer log was investigated.

Appendix J. Exploration of a Stationary Test Incorporating an Electronic Ignition Disable System. This appendix summarizes a study where EPA evaluated the use of an ignition disable device for both moving vehicle and stationary vehicle test procedures.

Appendix K. Further Study of the Ignition Disable Device. Data are included in this appendix to show results of EPA's efforts to refine the ignition disable device and to keep rpm overshoot within acceptable values.

Appendix L. Motorcycle Noise Estimated from Time/Distance Measurements During Acceleration in Urban Traffic Situations. This appendix summarizes a text program which was undertook by EPA to define motorcycle acceleration profiles and associated noise emissions as the Vehicle operated in an urban traffic situation.

Appendix M. Fractional Impact Procedure. The procedure used in assessing the health and welfare impact and benefits to be derived from regulating noise emission are summarized in this appendix.

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Appendix N. National Roadway Traffic Noise Exposure Model. This appendix includes a detailed discussion of the National Roadway Traffic Noise Exposure Model. This discussion encompasses the data, calculations, and assumptions that underline the model with focus on those details relevant to considerations of noise emission standards for motorcycles.

Appendix O. National Motorcycle Noise Control Emphasis Plan - Summary. This appendix is a summary of the Agency's plans to assist States and local governments in developing and implementing programs to control motorcycle noise. .

Docket Analysis. All of the questions, comments, and issues raised in the public hearings and in written submissions to the docket are addressed in detail.

SECTION 2

INDUSTRY DESCRIPTION

SECTION 2

INDUSTRY DESCRIPTION

2.1 Production Definition

For the purposes of the EPA motorcycle noise regulation all motorcycles which are designed and marketed for on-road operation are considered to be "street" motorcycles, subject to noise standards for street motorcycles. This category includes:

Street and highway motorcycles

Moped-type street motorcycles

Enduro motorcycles intended for limited street operation

Minicycles intended for street operation

Motor-driven scooters

This street motorcycle category encompasses vehicles having the following characteristics:

Approximately 50 to 1300 cc engines, developing from 1 to 100 horsepower

Two-stroke, four-stroke and rotary engines

One to six cylinders

Liquid, fan and air cooling systems

Two and three wheels

Light to heavy-weight

Shaft and chain drive

Manual and hydraulic torque converter automatic transmission

Moped-type street motorcycles are two-wheeled vehicles intended for use on streets and roads. These vehicles, which are popular in Europe and Asia and which have been already introduced into the U.S., have the following features:

Not more than 50 cc engines

Not more than 2 horsepower

Top speed less than 30 m.p.h.

For the purposes of the EPA noise regulation all motorcycles which are designed and marketed for off-road and off-road competition use, with the exception of motorcycles designed and marketed solely for use in closed-course competition events, are considered to be "off-road" motorcycles. This off-road motorcycle category includes:

Off-road, trail, and cross-country motorcycles

Enduro motorcycles not intended for street operation

Minicycles not intended for street operation

Trials motorcycles

All-terrain motorcycles not intended for street operation

This off-road category encompasses vehicles having the following characteristics:

50 to 750 cc engines

Two-stroke and four-stroke engines (great majority two-strokes)

Single cylinder

Air cooled

Two and three wheels

Light-weight

Chain drive

Manual, centrifugal clutch and continuously variable (belt) automatic transmission

For the purpose of the EPA noise regulation all motorcycles designed and marketed solely for use in closed-course competition events are considered competition motorcycles and are not subject to EPA noise control standards. They are however, subject to the labeling provisions of the motorcycle noise regulation. Closed-course competition events include: short track, dirt track, drag race, speedway, hillclimb, ice race, and the Bonneville Speed Trials.

Two and three wheeled tractors are not considered to be motorcycles for the purpose of the EPA motorcycle noise regulation. Also, electric and battery-powered motorcycles are not subject to the provisions of the regulations.

2.2 New Vehicle Manufacturers

More than 30 different manufacturers from all over the world sell motorcycles in the U.S. Manufacturers described in the Motorcycle Industry's Council's 1978 Statistical Annual are listed in Table 2-1.

Almost all foreign motorcycle manufacturers have companies in the U.S. distributing their products. The four major Japanese companies have wholly owned subsidiaries located in Sourthern California. Most of the smaller manufacturers are represented by independent distributing firms who represent their brand under contractual arrangements. Distributors are listed in Table 2-1 with the associated manufacturers.

Along with motorcycle manufacturers there are a few other U.S. companies that are involved to some extent in the OEM (original equipment manufacturer) segment of the market. These are companies which supply major components such as exhaust systems and engines to the motorcycle manufacturers. Representative companies in this category are:

Company	Component	Motorcycle
Nelson Industries	Mufflers	Harley-Davison
Briggs & Stratton	Engines	Heald
Tecumseh	Engines	Heald
Wisconsin	Engines	Heald

Most of these companies are not entirely dependent on the motorcycle industry, but sell their products to manufacturers in other industries such as automobiles, lawn mowers, and snowmobiles.

The remainder of the new motorcycle industry description is oriented primarily toward the manufacturers of full-sized 2-wheel motorcycles, since this segment is by far the largest element in the industry in terms of number of units sold.

2.2.1 Market Shares and Sales

The new motorcycle manufacturing segment of the industry is characterized by a small number of manufacturers which have significant sales in the U.S., and a large number of manufacturers with very limited sales in the U.S. Total industry sales figures since 1969 are shown in Figure 2-1. Available sales and market share data for each of the 10 leading companies are listed in Table 2-2.

In 1978, the five leading manufacturers (Honda, Yamaha, Kawasaki, Suzuki and AMF/Harley-Davidson) had 96.4 percent of the market, based on the number of new motorcycles registered. This is only an approximation because an estimated 30 percent of all motorcycles sold are not registered; however, market share inaccuracies are not likely to be great because all five sell the types of models that are likely to be unregistered. Of the individual brands, the largest share of the market is held by Honda, which had 35.9 percent of the market, followed by Yamaha - 25.9 percent, Kawasaki - 15.0 percent, Suzuki - 13.3 percent, and Harley-Davidson - 6.3 percent.

All other manufacturers combined shared approximately 4 percent of the market, and none individually had a share over 1 percent. Approximately 17 companies have less than 0.1 percent. These figures may be slightly understated since many of the companies with limited U.S. sales specialize

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Table 2-1

MOTORCYCLE MANUFACTURERS AND DISTRIBUTORS

BRAND	U.S. DISTRIBUTOR	COUNTRY OF MANUFACTURE
AMMEX	Apache Limited	Mexico
Arco/E-Z Rider	Dialex	U.S.
Bajaj	Bajaj America, Inc.	India
BMW	Butler & Smith - East Butler & Smith - West	West Germany
Benelli/Moto Benelli	Cosmopolitan Motors Benelli East, Inc.	Italy
Bultaco	Bultaco International Ltd.	Spain
Can-AM	Bombardier Corporation	Canada
Carabela	Cycle - Kraft Racers, Inc.	Mexico
CCM	CCM Imports America	England
Ducati	Berliner Motor Corp.	Italy
Gemini	Bulldog Manufacturers	Taiwan
Harley-Davidson	Harley-Davidson Motor, Inc.	U.S.
Heald	Heald, Inc.	U.S.
Hercules	Sachs Motors Corp. of U.S.A.	West Germany
Honda	Honda Motor Co. Ltd. American Honda Motor	Japan
Husqvarna	Husqvarna Motorcycle Co, Inc.	Sweden
Indian	Seneca Motorcycle Corp.	Taiwan
Italjet	Italjet U.S.A.	Italy
Jawa/CZ	American Jawa Ltd.	Czechoslovakia
KTM	KTM America	Austria
Kawasaki	Kawasaki Heavy Industries Kawasaki Motors Corp., U.S.A.	Japan
Lambretta	Scooter Corp. of America	Spain
Laverda	Slater Brothers	Italy
Maico	Maico Motorcycles, Inc. Maico West Debenham Imports	West Germany
Montesa	Cosmopolitan Motors, Inc. Viva Distributing Co.	Spain
Moto Guzzi	Berliner Motor Corps. Premier Motor Corporation	Italy
Moto Morini	Herdan Corporation	Italy

Table 2-1 (cont.)

BRAND	U.S. DISTRIBUTOR	COUNTRY OF MANUFACTURE
Ossa	Ossa Sales Corporation	Spain
Puch	Steyr Daimler Puch	Austria
Rickman	Target Products	England
Sachs	Sachs Motor Corp. of U.S.A.	West Germany
Suzuki	Suzuki Motor Co., Ltd. U.S. Suzuki Motor Corp.	Japan
Tri-Rod	Bletz Industries, Incl	U.S.
Triumph	Triumph Motorcycles	England
Vespa	Vespa of America Corp.	Italy
Yamaha	Yamaha Motor Co., Ltd. Yamaha Motor Corp., U.S.A.	Japan

Sources: 1. "1978 Motorcycle Statistical Annual", Motorcycle Industry Council.
2. Discussions with the Motorcycle Industry Council, June, 1980.
3. Individual conversations with motorcycle distributors and manufacturers, June, 1980.

Figure 2-1

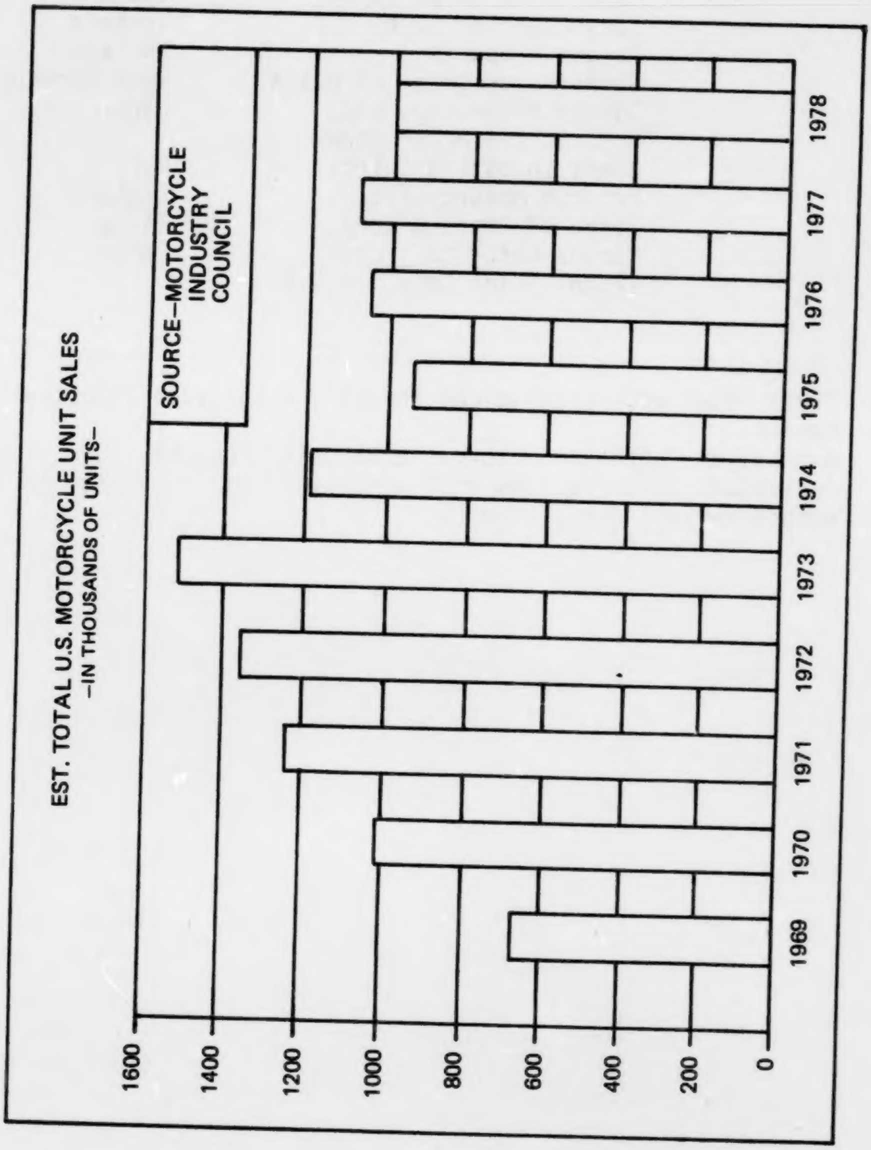
EST. TOTAL U.S. MOTORCYCLE UNIT SALES
–IN THOUSANDS OF UNITS–
SOURCE–MOTORCYCLE INDUSTRY COUNCIL
1600
1400
1200
1000
800
600
400
200
0
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978

Table 2-2

Motorcycle Manufacturer Sales and Market Share Data: 1978

RANK	Brand Manufacturer	Location/Mfg. Location(s)	Approx. Annual Retail Sales Range ($M)*	Percentage of New Registration**	Cumulative Percentage
1.	Honda	Japan	500*	35.9	35.9
2.	Yamaha	Japan	350-400	25.9	61.8
3.	Kawasaki	Japan	200-250	15.0	76.8
4.	Suzuki	Japan	150-200	13.3	90.1
5.	Harley-Davidson	U.S.	100-150	6.3	96.4
6.	Norton-Triumph	U.K.	10- 20	.8	97.2
7.	BMW	Germany	<10	.6	97.8
8.	Husqvarna	Sweden	<10	.5	98.3
9.	Bultaco	Spain	<10	.3	98.6

* U.S. motorcycle sales only (estimate derived from R. L. Polk registration data).

** Based on 1978 data for number of new motorcycles registered (R. L. Polk registration data).

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in off-road models which are generally not registered. Market share trends for the five largest companies in the past few years are shown in Figure 2-2. In 1978, Kawasaki and Honda market shares declined, while Yamaha, Suzuki, and Harley-Davidson market shares increased.

The distribution of sales ranges has a similar dispersion. Honda's annual retail sales in the U.S. are estimated to be over $500 million. Sales for each of the other four leading manufacturers are estimated to be between $100 million and $400 million. One manufacturer has annual sales estimated at between $10 to $20 million. All other companies are estimated to have less than $10 million in annual retail sales in the U.S.

Market shares for product categories defined by engine displacement size are shown in Table 2-3. The Japanese manufacturers are the top four manufacturers in all categories except the 750 cc and above category, where Honda and Harley-Davidson are the leaders.

2.2.2 Product Lines

There are major differences in the products offered by the manufacturers. Yamaha and Suzuki are manufacturers that offer models in every category (See Table 2-4). Yamaha has 30 models and Honda has approximately 23 different models in all size and function categories. Harley-Davidson has 8 models, all of which are in the large street model category. Most of the other manufacturers have model lines that are limited to some extent. Many of the others specialize in large motorcycles, small and medium sized dual-purpose or off-road motorcycles.

Most models in the large street motorcycle category and almost all Honda models have 4-stroke engines. Kawasaki, Yamaha, and Suzuki have both 2-stroke and 4-stroke models. The other manufacturers rely principally on 2-stroke engines. Two manufacturers have models with rotary engines (Suzuki and BMW). A list of engine types by manufacturers is provided in Table 2-5.

2.2.3 Motorcycle Prices

In general, European motorcycles, particularly in the street motorcycle category, have higher retail prices than those of major Japanese or U.S. brands. Figure 2-3 shows a comparison of prices versus engine displacement size for various street models listed in the N.A.D.A. Motorcycle Appraisal Guide. In the street category, European manufacturers generally offer a limited number of models at premium prices.

Price comparison for off-road motorcycles are more difficult because of the multitude of specialized functions of off-road motorcycles. However, the Japanese brands are typically 10 to 20 percent less in price for equivalent sized off-road models.

The Secretary of Treasury determined in 1978 that Honda, Yamaha, and Kawasaki had violated Section 201(a) of the 1921 Anti-dumping Act. U.S. sales prices for these manufacturers were found to be lower than their home market or third country (market) prices. The revised weighted average margins on overall sales compared were as follows: Honda, 2.6 percent; Yamaha, 0.82 percent; and Kawasaki, 6.9 percent. However, the U.S. International Trade Commission determined that "... there is no likelihood of injury or prevention of establishment of an industry in the United States by reason of sales of motorcycles from Japan at less than fair value." Therefore, no penalties were imposed on these manufacturers, nor were they forced to increase their prices.[1]

2.2.4 Typical New Motorcycle Manufacturers

Manufacturers of full sized motorcycles can be classified in the following manner:

- Major Japanese Motorcycle Manufacturers

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[1] Motorcycles from Japan, United States International Trade Commission, Washington, D.C., USITC Publication 923, November 1978.

Figure 2-2

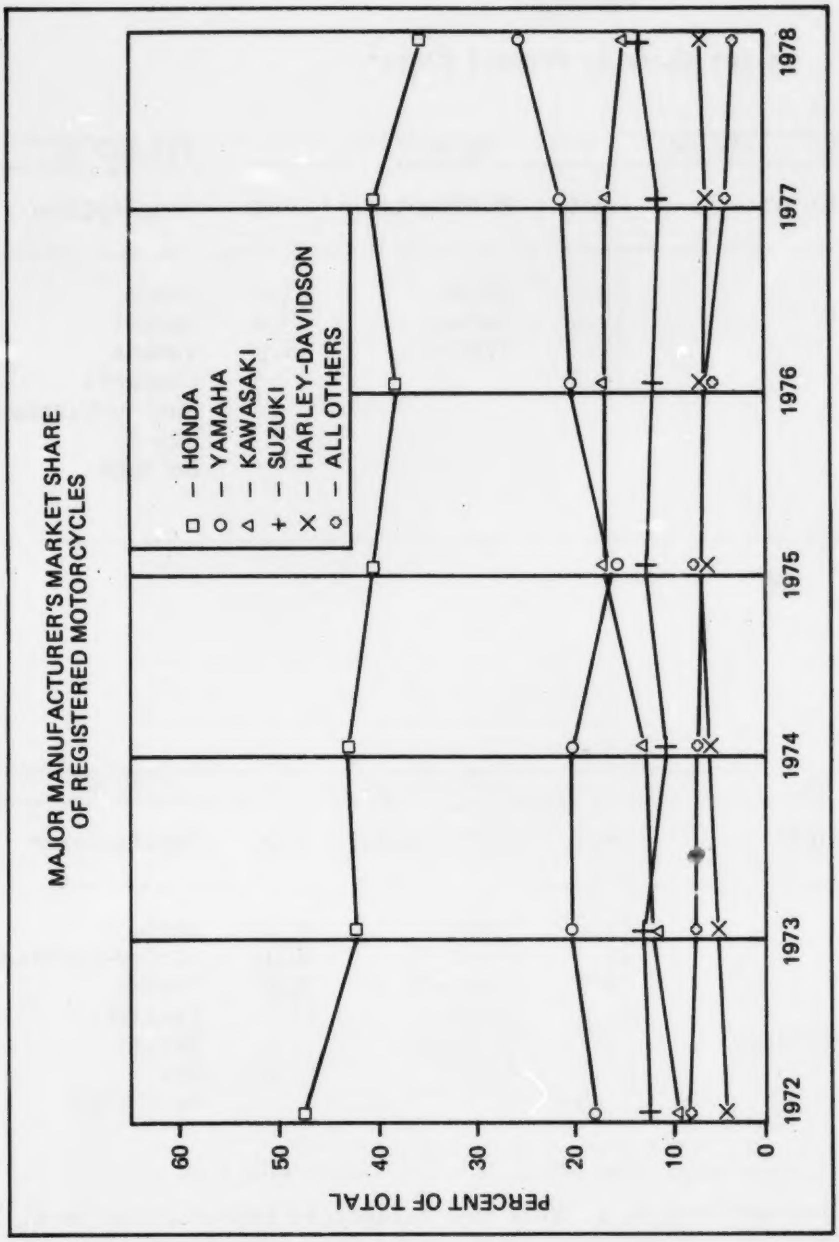

MAJOR MANUFACTURER'S MARKET SHARE OF REGISTERED MOTORCYCLES
□ — HONDA
○ — YAMAHA
△ — KAWASAKI
+ — SUZUKI
X — HARLEY-DAVIDSON
◇ — ALL OTHERS
PERCENT OF TOTAL
60
50
40
30
20
10
0
1972
1973
1974
1975
1976
1977
1978

Table 2-3

Market Share By Product Class*

RANK SIZE	Minibikes >50 cc		50-99 cc		100-169 cc	
	Manufacturer	Pct.	Manufacturer	Pct.	Manufacturer	Pct.
1.	Yamaha	48.2	Honda	85.5	Honda	31.6
2.	Kawasaki	19.6	Suzuki	9.0	Suzuki	27.9
3.	Honda	17.2	Yamaha	5.5	Yamaha	20.9
4.	Suzuki	14.9			Kawasaki	18.5
5.					Harley-Davidson	.8
					Can-Am	.2
					Bultaco	.1

RANK SIZE	170-349 cc		350-749 cc		>750 cc	
	Manufacturer	Pct.	Manufacturer	Pct.	Manufacturer	Pct.
1.	Yamaha	32.2	Yamaha	37.6	Honda	31.9
2.	Suzuki	23.3	Honda	30.1	Harley-Davidson	21.9
3.	Honda	19.8	Kawasaki	20.6	Yamaha	17.3
4.	Kawasaki	19.6	Suzuki	11.3	Kawasaki	15.5
5.	Harley-Davidson	5.7	Bultaco	.4	Suzuki	10.5
6.	Bultaco	.9	BMW	.7	BMW	2.0
7.	Can-Am	.5			Moto Guzzi	.7

---

* Market share as determined from R. L. Polk New Motorcycle Registration Data, 1978. Non-registered motorcycles are not accounted for in this tabulation.

Table 2-4

MOTORCYCLE MANUFACTURERS PRODUCT LINE BY PRODUCT CATEGORY

MANUFACTURER	STREET-LEGAL					OFF-ROAD			
	Under 1000 cc	100-169 cc	170-349 cc	350-749 cc	750cc &Over	Under 100 cc	100-169 cc	170-349 cc	350-749 cc
Ammex								X	
BMW				X	X				
Benelli/Motto Benelli			X	X	X				
Bultaco									
Can-Am								X	X
Carabela							X	X	X
Ducati					X				
Gemini							X		
Harley-Davidson					X				
Heald									
Hercules/Sachs							X	X	
Honda	X	X	X	X	X	X	X	X	
Husqvarna							X	X	X
Kawasaki	X	X	X	X	X	X	X	X	
Laverda				X	X				
Montesa		X	X			X	X	X	X
Ossa			X	X				X	X
Rickman					X				
Suzuki	X	X	X	X	X	X	X	X	X
Tri-Rod							X		
Triumph					X				
Yahama	X	X	X	X	X	X	X	X	X

Sources:
-. N.A.D.A. Motorcycle/Moped Guide, First Quarter, 1978.
-. Conversations with individual distributors and manufacturers, June, 1980.

Table 2-5

ENGINE TYPES BY MANUFACTURER

Brand/Manufacturer	Engine Type(s)
Ammex	2-Stroke
BMW	4-Stroke
Benelli/Moto Benelli	2-Stroke/4-Stroke
Can-AM	2-Stroke
Carabela	2-Stroke
Ducati	4-Stroke
Harley-Davidson	2-Stroke/4-Stroke
Hercules/Sachs	2-Stroke
Honda	2-Stroke/4-Stroke
Husqvarna	2-Stroke
Kawasaki	2-Stroke/4-Stroke
Laverda	4-Stroke
Montesa	2-Stroke
Ossa	2-Stroke
Rickman	2-Stroke
Suzuki	2-Stroke/4-Stroke
Triumph	4-Stroke
Yamaha	2-Stroke/4-Stroke

Sources:
- N.A.D.A. Motorcycle/Moped Guide, First Quarter, 1978.
- Conversations with individual distributors and manufacturers, June 1980.

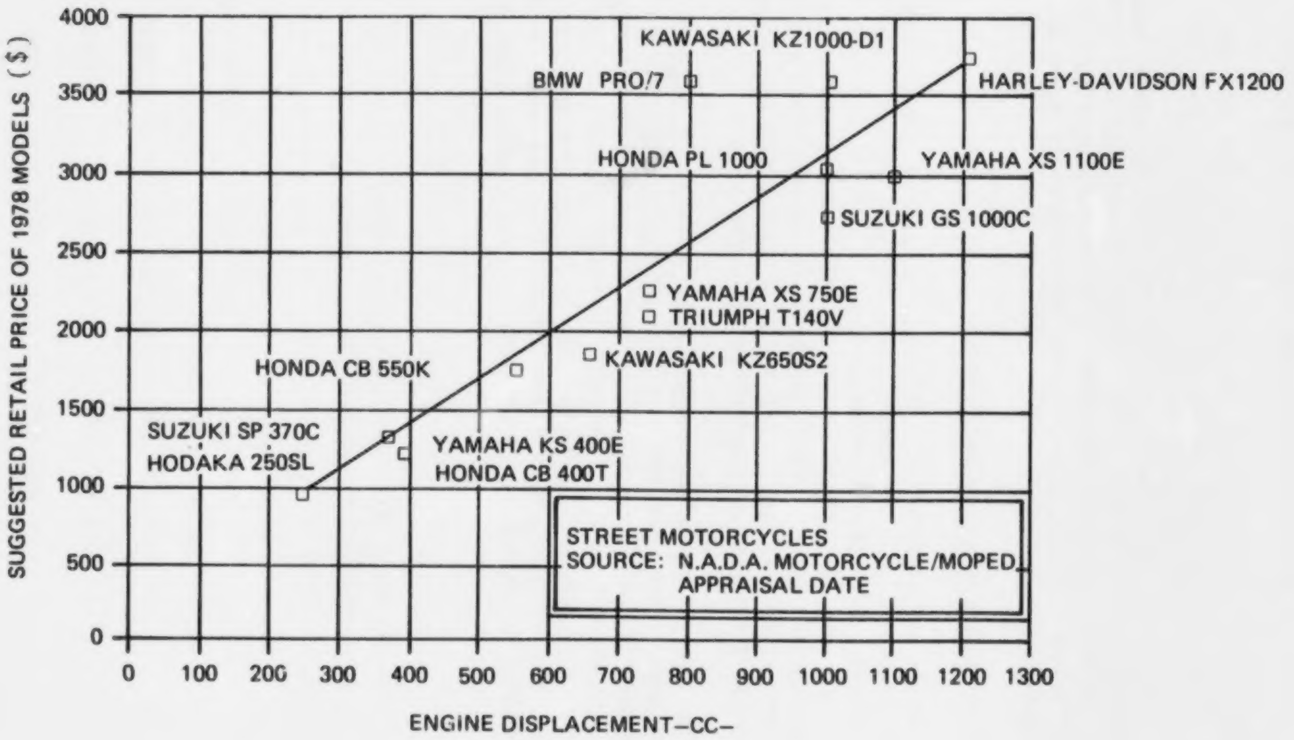


Figure 2-3

SUGGESTED RETAIL PRICES OF SELECTED MODELS
VERSUS ENGINE DISPLACEMENT (1977 PRICES)

- Major U.S. motorcycle manufacturer - AMF/Harley-Davidson
- U.S. motorcycle manufacturers with limited U.S. sales
- Foreign manufacturers with limited U.S. sales

A major motorcycle manufacturer is defined as one having U.S. retail level sales of motorcycles and parts of $100 million or over annually. Manufacturers with "limited" sales have less than $100 million in U.S. retail sales annually. Actually, most manufacturers in this category have less than $10 million in annual retail sales. The categories are defined in this manner because economic impacts on typical firms in each category are likely to be significantly different. Each category is described in more detail in the following paragraphs.

Major Japanese Motorcycle Manufacturers

Major motorcycle manufacturers defined here are those Japanese companies with over $100 million in annual U.S. retail sales. There are four such companies (Honda, Kawasaki, Yamaha, Suzuki) which are all very large industrial concerns, and motorcycles are a major or significant component of total company operations. Annual motorcycle production and export for these companies are listed in Table 2-6. Data indicating the financial size and strength of these companies are provided in Table 2-7.

There is some variation in the proportionate level of motorcycle-related sales in each company. Honda is the world's largest motorcycle manufacturer, and 40 to 50 percent of total corporate revenues come from motorcycle sales. Kawasaki and AMF are essentially large conglomerates; motorcycle-related sales for these two companies are an estimated 10 to 20 percent of total corporate revenues. Suzuki and Yahama are smaller companies, and have a much larger proportion (50 percent or more) of their total sales coming from motorcycles.

Table 2-6

JAPANESE MOTORCYCLE MANUFACTURERS
PRODUCTION AND EXPORTS, 1976

Manufacturer	Production (Units)	Export (Units)	Percentage
Honda	1,928,576	1,230,797	64%
Yamaha	1,169,175	795,341	68%
Suzuki	832,941	632,233	76%
Kawasaki	284,478	263,760	93%
Total	4,214,170	2,922,131	69%

Source: Japan Economic Yearbook, 1977/1978.

Table 2-7

MAJOR MOTORCYCLE MANUFACTURERS FINANCIAL DATA

COMPANY	COUNTRY	INDUSTRY	SALES ($000)	ASSETS ($000)	NET INCOME ($000)	STOCK-HOLDERS EQUITY $000	EMPLOYEES	WORLD* RANKING		SOURCE
								1976	1975	
Kawasaki Heavy Industries	Japan	Shipbuilding Industrial Mach. Motorcycles	1,964,628	2,958,589	33,634	368,950	38,410	111	104	1
Honda Motor	Japan	Motorcycles Automobiles Far Machine	2,435,632	1,905,803	60,902	402,270	28,218	90	107	1
BMW (Bayerische Motern Werke)	Germany	Automobiles Motorcycles	1,784,436	949,492	50,792	282,346	30,192	129	161	1
Suzuki Motors	Japan	Automobiles Motorcycles	613,456	491,391	8,098	102,271	9,000	351	346	1
Yamaha Motor	Japan	Motorcycles Rec. Vehicles	554,234	329,905	7,360	95,806	7,965	386	353	1
AMF/Harley Davidson	U.S.	Motorcycles Leisure Products Industrial Products	1,229,226	827,411	42,720	341,456	25,152	NA	NA	2

* Ranked by Sales; excludes U.S. Companies

SOURCE:

1. Fortune Magazine, August 1977 (Fiscal Year 1976 Data)
2. Fortune Magazine, May 1978 (Fiscal Year 1977 Data)

Approximately 20 to 40 percent of total Japanese motorcycle production is exported to the U.S. Kawasaki's U.S. sales are higher than this average, while Suzuki's are somewhat lower.

Characteristics of a major Japanese motorcycle manufacturer are shown in Table 2-8. On the average, each Japanese firm produces one million motorcycles annually, of which approximately 27 percent are exported to the U.S. At the retail level, these motorcycles are worth approximately $250 million to $300 million Production capacities of the companies range from 40,000 units per month and greater.

Several features of Japanese financial practices and economic conditions should be noted. In general, Japanese companies are highly leveraged firms. The debt to equity ratios in the capital structure of a typical Japanese company are much higher than in U.S. firms. This makes Japanese companies more vulnerable in the event of downturns in business activity--large interest expenses can create cash flow problems. However, Japan has a central bank (Bank of Japan) that has very strong fiscal authority. The Bank of Japan can direct bank loans to companies with financial problems, which largely alleviates the hazards associated with high leverage. However, if the condition is chronic, companies in Japan declare bankruptcy just as they do in the U.S. In general, profit margins of Japanese companies are lower than those of U.S. companies, but direct comparison is somewhat meaningless due to the difference in capitalization, as noted above. Because of the high degree of leverage, lower profit margins can nevertheless net the same return on owners' investment as with U.S. companies.

A factor that may significantly impact the trade balance between the U.S. and Japan is the fluctuating value of the dollar versus the Japanese yen. For example, the value of the dollar has declined by more than 30 percent from 1976 to 1979 (see Figure 2-4). Thus the impact of the dollar/yen relationship on motorcycle exports is yet to be determined.

A brief profile of the major motorcycle manufacturers is provided in the following paragraphs.

Honda

The Honda Motor Company is located in Tokyo, Japan, and sells automobiles, motorcycles, and miscellaneous non-vehicular products. The company earned $60.9 million in 1976 on sales of $2,435 million. Motorcycle sales accounted for 46 percent of the total sales, automobiles accounted for 35 percent of the total, and non-vehicular products sales made up the remainder. Honda is the world's largest motorcycle manufacturer and has the largest share of the U.S. motorcycle market. In 1976, the company manufactured nearly 2 million motorcycles, an estimated 20 to 30 percent of which were exported to the U.S.

The company has put a strong emphasis on R&D and has a separate wholly-owned subsidiary, Honda R&D Company, Ltd., which conducts research and development for both the automobile and motorcycle product lines. In recent years the company has put considerable emphasis on noise control research, and the company is well positioned in this area. Because of its size, finan-

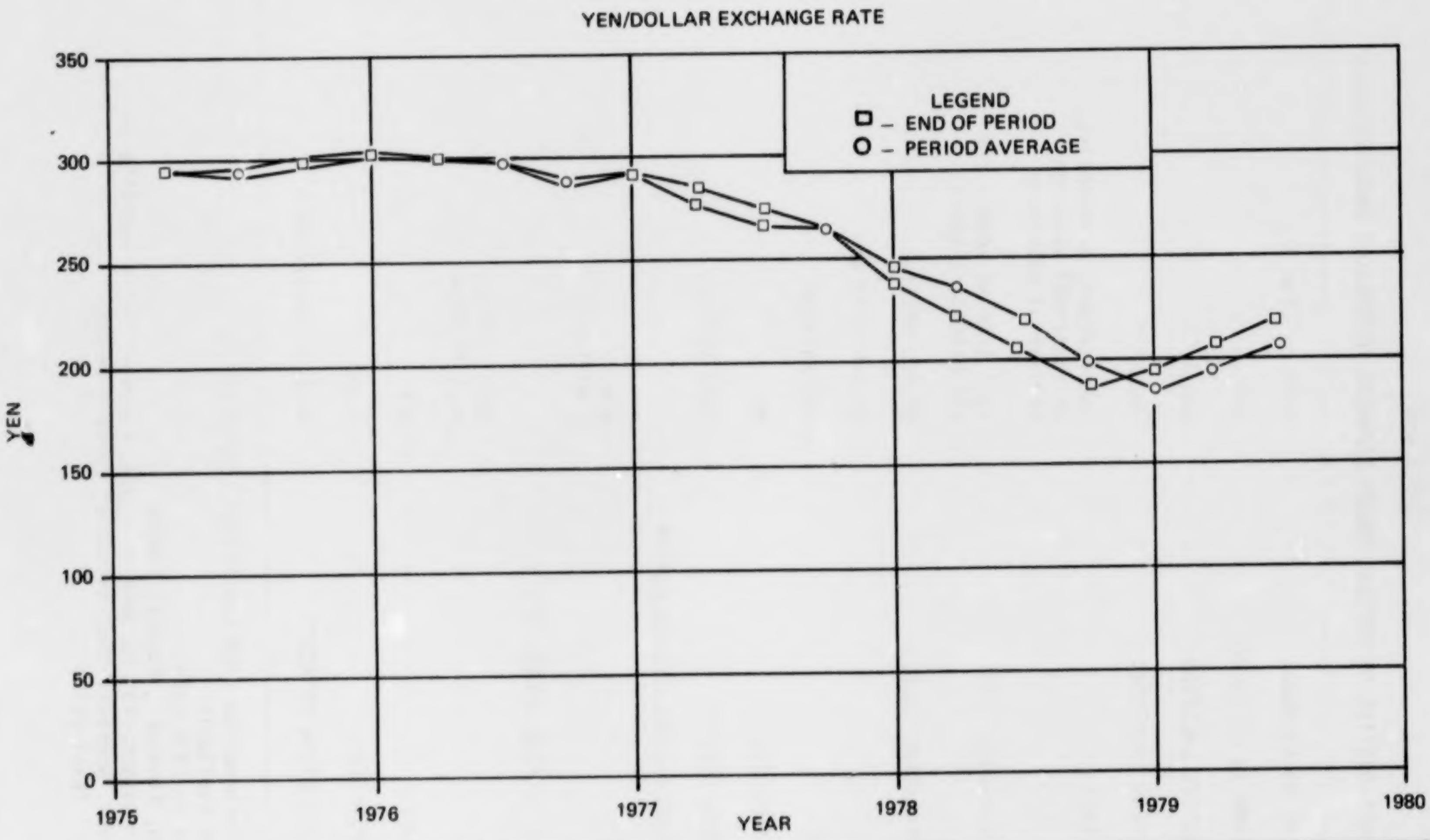
Table 2-8

CHARACTERISTICS OF TYPICAL MAJOR JAPANESE MOTORCYCLE MANUFACTURERS*

U.S. RETAIL SALES RANGE	$100 Million +
NO. OF FIRMS IN CATEGORY:	4**
ADMINISTRATIVE LOCATION:	Japan
MANUFACTURING LOCATION:	Japan***
PRODUCT LINE:	Motorcycles, Automobiles, Recreational Vehicles, Industrial Machinery
MOTORCYCLE PRODUCT LINE:	Full line of models for all product classes
TOTAL CORPORATION SALES:	$1,400 Million
ASSETS:	$1,400 Million
NET INCOME:	$28 Million
NET PROFIT MARGIN:	2%
STOCKHOLDERS EQUITY:	$242 Million
TOTAL MOTORCYCLE RELATED SALES****	
DOLLARS	N.A.
UNITS	1 Million
MOTORCYCLE RELATED SALES, U.S.:	
DOLLARS	$280 Million
UNITS	0.26 Million
MARKET SHARE:	22%
NO. OF EMPLOYEES:	8,000
MAXIMUM PRODUCTION CAPACITY	40,000+ Units/Month

Source: Information from individual companies
N.A. - Not Available
* Based on 1976 data
** Honda, Kawasaki, Suzuki, Yamaha
*** All manufacturing is done in Japan, Kawasaki has a facility in Lincoln, Nebraska that assembles certain models
**** Retail level sales

Figure 2-4


YEN/DOLLAR EXCHANGE RATE
LEGEND
□ – END OF PERIOD
○ – PERIOD AVERAGE
YEN
350
300
250
200
150
100
50
0
1975
1976
1977
1978
1979
1980
YEAR

cial strength, planning and research commitment and technical facilities, Honda is likely to experience the least adverse impact of any of the other companies in the industry. The only major disadvantage that Honda has is the number of models it carries in its product line. Each model, or possibly a smaller number of subset model categories, will require individual effort and time for noise control research and development.

Kawasaki

Kawasaki motorcycles are manufactured by Kawasaki's Engine and Motorcycle Group, which provides 20 percent of the corporation's total sales. This particular group is located in Akashi, Japan, and manufactures motorcycles, gas turbine engines, chemical machinery and industrial robots. The parent corporation, Kawasaki Heavy Industries, Ltd., is one of Japan's biggest industrial concerns, with total sales approaching two billion dollars. Of the four major Japanese manufacturers, Kawasaki produces the lowest total number of motorcycles, but exports the highest percentage of its total production to the U.S.

Kawasaki has a motorcycle assembly facility in Lincoln, Nebraska, but all engine assembly and most motorcycle assembly is done in Japan. Approximately 200 employees are involved in the U.S. motorcycle manufacturing operations.

The company has a technical research laboratory equipped with sophisticated monitoring and diagnostic instruments. A noise research effort has been in progress for several years, and Kawasaki's capability in this area (plant, equipment, personnel) appears to be well established.

Suzuki

Suzuki Motors is a leading manufacturer of motorcycles and lightweight automobiles with 2-stroke engines. Company sales increased from $467 million to $613 million between 1970 and 1976, an increase of 30 percent. Profits during this period declined slightly from $10.9 million to $8.1 million.

Yamaha

Yamaha Motor Company manufactures and sells motorcycles, mopeds, bicyles, snowmobiles, recreational boats, engines and swimming pools. In addition the company develops and operates recreational facilities.

A large proportion of the company's revenue comes from motorcycle sales. In 1976, the company manufactured slightly over one million motorcycles. Sixty-eight percent were exported, and approximately 20 to 30 percent were exported to the U.S.

Yamaha has modern R&D facilities and equipment, and has a demonstrated capability for noise control research and design.

Major U.S. Motorcycle Manufacturer - AMF/Harley-Davidson

AMF/Harley-Davidson is the only remaining major U.S. motorcycle manufacturer. The company was started in 1903, and has specialized in manufacturing large touring motorcycles. In 1968, the company was acquired by

AMF, Inc., as part of AMF's extensive diversification effort. In 1977 AMF earned $42.7 million from sales of slightly over $1.2 billion. AMF products are primarily oriented toward the leisure and industrial products market; approximately 60 percent of sales and 50 percent of earnings come from leisure products.

A breakdown of revenues by class of products in AMF's 1977 annual sales indicated that motorcycles and other travel vehicles provided $203.6 million in revenues, or appproximately 17 percent of AMF's sales. Motorcycles and motorcycle parts sales account for most of this revenue, estimated to be between $100 million and $200 million annually.

At the present time, the Harley-Davidson product line consists of eight large touring models, all of which are 1000 cc or more. A sidecar option is available for the larger models.

A total of 51,000 Harley Davidsons were registered in 1977.[2] The larger models averaged a retail price of $3,200 or more; retail sales for these models alone were approximately $100 million. Harley-Davidson's sales on a unit basis represented a 6.1 percent share of the market in 1977, based on registration data. Harley-Davidson's market share on a dollar basis is somewhat higher, since its product line is oriented toward the larger, more expensive motorcycles. In 1978, Harley-Davidson had 31.9 percent of the market for motorcycles 750 cc and over. Sales and financial characteristics of AMF/ Harley-Davidson are shown in Table 2-9. Harley-Davidson recently discontinued production of its lightweight motorcycles at their wholly-owned subsidiary in Italy.

Most people in the motorcycle industry believe that Harley-Davidson has a unique niche in the market place. Buyers of the large Harley-Davidson models demonstrate considerable loyalty to the brand, and are relatively insensitive to design advancements and marketing campaigns of competing models. It is the only U.S. motorcycle manufacturer which has survived from the early 1900's to the present, resulting in the evolution of a very strong consumer tradition. As evidence, Harley-Davidson has increased its market share in spite of increased competition from major Japanese manufacturers in the large street motorcycle category.

The strong brand loyalty that was indicated by industry sources to be characteristic of Harley-Davidson buyers would seem to accord Harley-Davidson certain advantages. It appears that Harley-Davidson sales are considerably less sensitive to both price increases and declines in real income than are other brands.

Large Harley-Davidsons feature a longitudinal 45 degree V-Twin engine with common crank pin; a unique design in today's motorcycle market. This engine configuration provides Harley-Davidson motorcycles with low center of gravity, narrow profile, and powerful low-end torque. It also features a

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[2] Motorcycle Industry Council, "Manufacturers Shipment Reporting System".

Table 2-9

CHARACTERISTICS OF MAJOR U.S. MOTORCYCLE MANUFACTURING FIRM (AMF/HARLEY-DAVIDSON)(1)

CATEGORY:	U.S. Motorcycle related sales over $100 Million annually.
LOCATION:	Milwaukee, Wisconsin
CORPORATE PRODUCT LINE:	Leisure products (including motorcycles) Industrial products and machinery.
MOTORCYCLE PRODUCT LINE:	Milwaukee, Wisconsin and York, Pennsylvania plants: large touring motorcycles (1,000 cc and 1,200 cc)
TOTAL CORPORATION SALES:	$1229.2 Million
NET INCOME:	$42.7 Million
NET PROFIT MARGIN:	3.5%
ASSETS:	$827.4 Million
STOCKHOLDER'S EQUITY	$341.5 Million
MOTORCYCLE AND TRAVEL VEHICLES SALES	$203.6 Million(2)
MOTORCYCLE RELATED SALES, U.S. DOLLARS:	$100+ Million
UNITS REGISTERED (TOTAL))	51,000
MARKET SHARE:	6.1%
NO. OF EMPLOYEES, MOTORCYCLE RELATED:	3,700 (as of 1979)(3)

Source: Except where otherwise indicated, AMF Annual Report, 1977.

(1) Harley-Davidson, AMF's largest manufacturing subsidiary.

(2) Motorcycles sales make up a very large percentage of motorcycle and travel vehicle sales, but exact percentage not available.

(3) Cycle News, May 23, 1979.

low frequency asymmetrical exhaust note that is unique and which has customer appeal. In addition, the V-Twin engine provides specialized styling for these motorcycles. The manufacturer believes that this unique "sound" and appearance must be retained to preserve demand for Harley-Davidson motorcycles.

Engines and parts for the large motorcycles are manufactured in Harley-Davidson's Milwaukee, Wisconsin facilities, and are assembled in a York, Pennsylvania plant. Approximately 3,700 people are directly employed in the production of motorcycles, parts, and accessories. Approximately 9,300 people are indirectly affected to some extent at supplier plants, distribution and sales locations, and Harley-Davidson dealerships. Harley-Davidson is more vertically integrated than most other manufacturers, in that it makes many of the parts and components which other manufacturers normally buy from suppliers.

From a cost standpoint, Harley-Davidson suffers a disadvantage in view of the fact that Harley-Davidson's production base is 50,000 units per year, as compared to the typical 270,000 units per year of its major competitors. Period costs such as R&D and depreciation are thereby allocated over lesser number of units. This disadvantage is tempered by the fact that Harley-Davidson has a lesser number of models to manage, and that its product line is composed of strictly large street motorcycles which can sustain larger cost increases than smaller models on a relative basis.

However, due in part to vehicle improvement, dealer orders in 1980 have increased to 80,000 units. To meet increasing demand for these motorcycles, and to improve efficiency, AMF, since it acquired Harley-Davidson, has been gradually retooling and automating plant equipment, rearranging plant layout, and strengthening its engineering operations. For example, the new five-speed transmission case for the Harley-Davidson FLT Tour Guide can be built by one man with automated equipment, while 14 men were required to build the older four-speed transmission case. With additional manufacturing improvements, vehicle production could be increased as high as 200,000 units per year within the next few years.*

U.S. Motorcycle Manufacturers with Limited U.S. Sales

A typical U.S. company is relatively young and small (less than $2-3 million in assets), manufactures 11,000 units and has annual sales in the $4 - $5 million range. U.S. employment for the companies ranges from 2 to 34 employees. The small U.S. company's product line is generally limited to minicycles, or small motorcycles (typically less than 185 cc) that are intended for off-road or dual purpose use. Characteristics of a typical U.S. company with limited sales is shown in Table 2-10. A brief description of some of these companies is contained in the following paragraphs.

Dialex (formerly Alexander Reynolds)

Dialex is located in Hackensack, New Jersey, and manufactures minibikes and go-karts. The minibikes use Tecumseh engines.

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*Source: Motorcycle; May, 1980

Table 2-10

CHARACTERISTICS OF TYPICAL SMALL U.S. MOTORCYCLE MANUFACTURERS*

RETAIL SALES RANGE:	Less than $10 Million
NO. OF FORMS IN CATEGORY:	10 - 20 (Est.)
ADMINISTRATION LOCATION:	U.S. (Typically Great Lakes area)
MANUFACTURING LOCATION:	Either U.S. or Foreign
PRODUCT LINE:	Limited number of specialty models
TOTAL MOTORCYCLE RELATED SALES**	
DOLLARS:	$5.0 Million
UNITS:	11,000
MARKET SHARE:	Less than 1.0%
ASSETS:	$2 Million
NET PROFIT MARGIN:	N/A
NET WORTH:	N/A
NO. OF U.S. EMPLOYEES, MOTORCYCLE RELATED:	20

Source: Information from representative companies.
* 1977
** Almost all companies in this category have all or very large part of revenues coming from motorcycle business.
N/A - Not Available

Bletz Industries

Bletz Industries is located in Mansfield, Ohio, and manufactures Tri-Rod, a three-wheel vehicle intended for off-road use. The Tri-Road uses Briggs-Stratton 3, 5, and 8 horsepower engines.

Heald

Located in Benton Harbor, Michigan, Heald manufactures two- and three-wheel cycles in kit form. The cycles use Briggs and Stratton and Tecumseh engines. The models are intended for trail and utility purposes (e.g., garden tractors and dump trucks).

Foreign Motorcycle Manufacturers with Limited U.S. Sales

There are over 30 foreign manufacturers with limited U.S. motorcycle sales. A typical company manufactures 20,000 units, of which 4,000 are exported to the U.S. This quantity represents less than one-half of one percent of the U.S. market, and is worth approximately $4 million in sales revenues. The product line is typically limited and concentrated in certain product categories. For example, many of the Italian companies such as Ducati, Laverda, Moto Benelli, Moto Guzzi, and Moto Morini, market large street motorcycles. Characteristics of a typical foreign motorcycle manufacturer with limited U.S. sales is shown in Table 2-11.

Descriptions of some of the companies are in the following paragraphs.

Benelli

Moto Benelli is an established Italian firm that is a subsidiary of DeTomaso Industries. Benelli markets 250 cc, 500 cc, 650 cc and 750 cc street motorcycles.

BMW

BMW is an extremely large manufacturer located in West Germany. Total corporation sales in 1974 approached $1 billion. Automobiles and large touring motorcycles are major product lines. According to registration data, BMW had a one percent share of the U.S. market in 1975, and ranked seventh among all manufacturers. BMW sells large touring motorcycles with horizontally opposed twin cyclinder engines and shaft drive. Like Honda, BMW can make use of expertise and facilities developed for the automobile market.

Can-Am

Can-Am motorcycles are manufactured by Bombardier, Ltd., a large Canadian firm that also manufactures snowmobiles, industrial vehicles, all-terrain tractors, and winter sport accessories and apparel. Can-Am specializes in high performance enduro and competition motorcross motorcycles. Bombardier makes 10,000 motorcycles per year.

Hercules

Hercules are manufactured by DKW/Hercules, part of the Wankel-Fichtel-Sachs Manufacturing Group, which is one of German's largest manufacturers of motorcycles. The Group is also a major supplier of engines to other motorcycle manufacturers. DKW primarily makes enduro and off-road motor-

Table 2-11

CHARACTERISTICS OF TYPICAL FOREIGN MOTORCYCLE MANUFACTURER WITH LIMITED U.S. SALES*

RETAIL SALES RANGE:	Less than $10 Million
NUMBER OF FIRMS IN CATEGORY:	25+
LOCATION:	Europe, Taiwan, Mexico, Canada
PRODUCT LINE:	Motorcycles, Bicycles, Mopeds
MOTORCYCLE PRODUCT LINE:	Limited number of speciality models
TOTAL CORPORATION SALES:	N/A
ASSETS:	N/A
NET PROFIT MARGIN:	N/A
NET WORTH:	N/A
TOTAL MOTORCYCLE RELATED SALES	
DOLLARS:	N/A
UNITS:	20,000
MOTORCYCLE-RELATED SALES, U.S.	
DOLLARS:	$4 Million (Est.)
UNITS:	4,000
MARKET SHARE:	Less than 1%
NO. OF EMPLOYEES (U.S. DISTRIBUTORS):	40

Source: Information from individual U.S. distributors of foreign manufacturers.

N/A - Not Available.

* 1975

cycles. DKW also markets a rotary engine model, although production of this model is relatively limited.

Husqvarna

Husqvarna is a large Swedish manufacturing company which produces engines, chain saws, appliances, sewing machines, as well as motorcycles. The company specializes in very high quality off-road, cross country and competition models. Approximately 75 percent of Husqvarna's total production is exported to the U.S.

Laverda

Laverda is an Italian motorcycle manufacturer that makes large street motorcycles whose product line is primarily in the 750-1000 cc size range.

Moped-type Street Motorcycles

Moped-type vehicles are street motorcycles intended for use on streets and roads. These vehicles were first introduced into the U.S. in 1975 after the National Highway Traffic Safety Administration relaxed its safety standards so that moped-type street motorcycles similar to the ones sold overseas could be imported.

Although nine American companies (See Table 2-11A) have entered the market, most of the moped-type street motorcycles sold in the U.S. are imported. Imports have risen from the 1975 level of 33,136 by 138 percent and 144 percentfor 1976 and 1977 respectively. For the first seven months of 1978 the number of moped-type street motorcycle imports is 284,494, a 176 percent increase over the same period in 1977. During 1980 the population of moped-type street motorcycles is expected to increase to over 1,000,000 vehicles.

Recent Moped sales are estimated by the Moped Association of America (MAA) as follows:

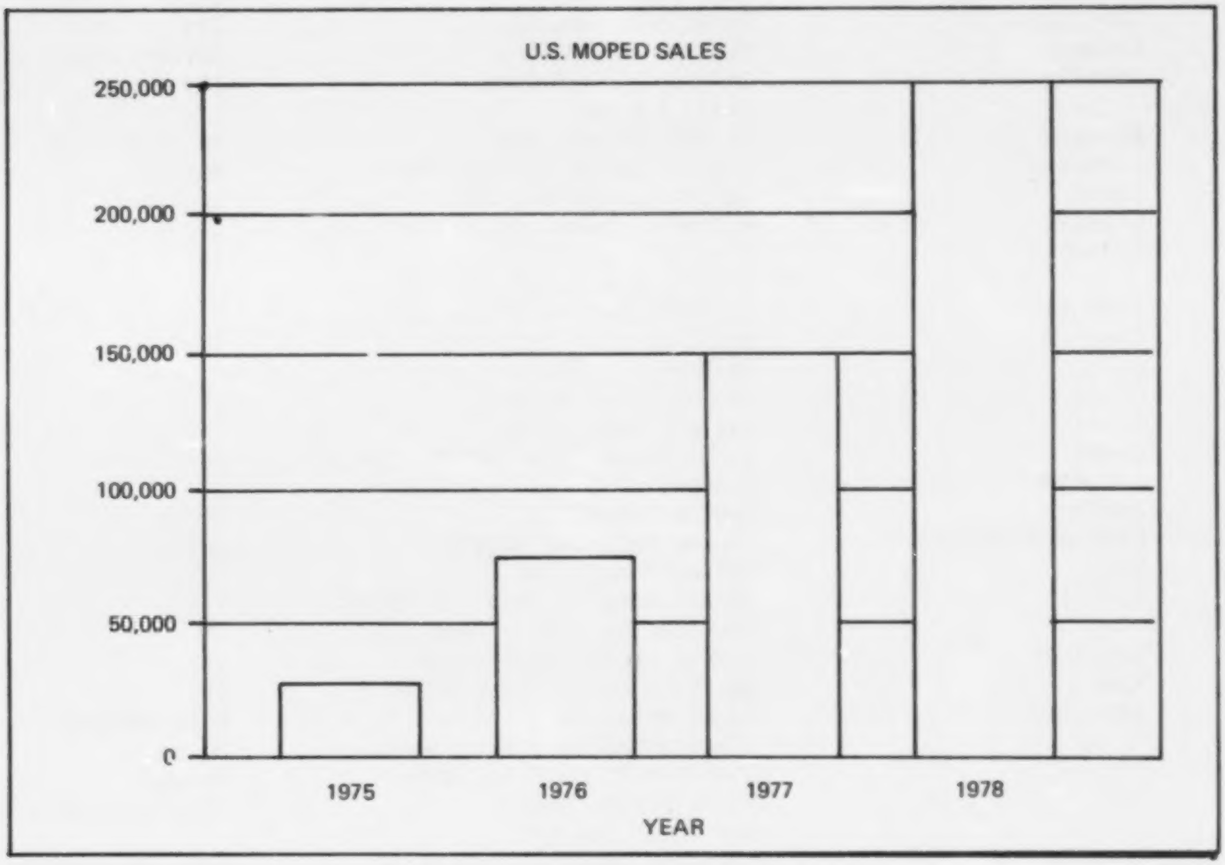
1975	25,000	Units
1976	75,000	Units
1977	150,000+	Units
1978	250,000	Units

This rapid growth is shown in Figure 2-[illegible]. Other Moped characteristics are summarized in Table 2-12.

2.3 Aftermarket Industry

The structure of the aftermarket segment of the industry is entirely different from the new motorcycle market segment. The aftermarket industry is primarily domestic, as compared with the primary product market itself which has become internationalized. There are an estimated 1500 companies in

Figure 2-5



Source: Moped Association of America

Table 2-11A

MOPED MANUFACTURERS AND DISTRIBUTORS

BRAND	U.S. DISTRIBUTOR	COUNTRY OF MANUFACTURE
AMF Roadmaster	AMF, Inc.	U.S.
Baretta	Baretta of America	Italy
Batavus	Batavus of America	Netherlands
Benelli	Cosmopolitan Motors Essex Subaru	Italy
Bermuda	Bermuda Bikes, Inc.	Belgium
Carabela	Cycle - Kraft Racers, Inc.	Mexico
Casal	Baltimore Cycles, Inc.	Portugal
Classic	Motron Corporation of America	Italy
Columbia	Midstates Appliance Tiger Cycle Manufacturing	Italy
Commuter	Columbia Manufacturing Co.	U.S.
Concord	Wheelsport Distributing Co. Columbus Cycle	Italy
Cosmo	Cosmopolitan Motors	
Cuyler	Cuyler Corporation	Italy
Derbi	Derbi Motor Corp. of America	Spain
E-Z Rider	Dialex	U.S.
Fantic	Fantic Moped, Inc.	Italy
Flying Dutchman	Flying Dutchman Mopeds	U.S.
Foxi	United Moped, Inc.	U.S.
Garelli	Agrati-Garelli Corp. of America American Garelli - West	Italy
Gadabout	Yankee Cycle Corporation	Italy
Hawk	American Moped Corporation	Italy
Hercules	Sachs Motor Corp. of U.S.A.	West Germany
Honda	American Honda Motor Company	Japan
Indian	American Moped Associates	Taiwan
Jawa	Essex Subaru Moped American Jawa Ltd.	Czechoslovakia
Kreidler	Kreidler Import Corporation	West Germany
Mobylette	Motobecane America Ltd.	France
Morini	Herdan Corporation	Italy
Motobee	Motobee Ltd.	Italy
Motron	Midway Distributing Co.	Italy
Moto Guzzi	Premier Motor Corporation	Italy
Murray	Murray Ohio Manufacturing Co.	U.S.
Negrini	Marina Mobili, Inc.	Italy

Table 2-11A (cont.)

BRAND	U.S. DISTRIBUTOR	COUNTRY OF MANUFACTURE
Pacer	Essex Subara Moped Allied Cycle Distributors AEON International Corporation	Italy
Panther	Panther Motorsport Industries	U.S.
Peddler's Choice	Halsey Distributors	Italy
Peugeot	Cycles Peugeot (U.S.A), Inc.	France
Pryer 3-Wheel	Pryer Industries	U.S.
Puch	Mopeds Midwest Steyr Daimler Puch of America Corp.	Austria
Sachs	United Moped Sachs Motor Corporation of U.S.A.	West Germany
Safari	Moped Distributors Motor Bikes Import	Italy
Scout	Intra Motor U.S.A.	Italy
Snark	Snark Mopeds, Inc.	Italy
Soni	Bajaj Scooter Corporation Paul Soni of America, Inc.	India
Sparta	Dursor U.S.A., Inc. Sparta/Moby	Netherlands
Tomos	U.S. Trade Representatives	Yugoeslavia
Tri-Ped	American Tri-Ped Corporation	U.S.
Yamaha	Yamaha Motor Corporation U.S.A.	Japan

Source: Individual conversations with moped distributors, June, 1980.

Table 2-12

MOPED-TYPE STREET MOTORCYCLE CHARACTERISTICS [1]

Introduced into the U.S.in 1975
    1975 sales: 25,000
    1976 sales: 75,000 (MAA estimate)
    1977 sales: 150,000[2]
    1978 sales: 250,000

Features:
    (A) 1-2 hp
    (B) 50 cc 2-stroke single cylinder engine
    (C) Top speed less than 30 m.p.h.
    (D) Pedal assisted for acceleration from complete stop
    (E) Automatic transmission (centrifgal clutch or direct drive)
    (F) Bicycle-type frame, brakes
    (G) 60-100 pounds, 120-200 m.p.g., $300-$500

Noise levels:
    60-69 dB at 50 feet (full throttle/top speed)[3]
    73 dB ISO procedure

Manufacturers:[4]
    Approximately 24 currently importing to U.S.
    Approximately 9 U.S. manufacturers

Markets:[5]

Bicycle Shops	45%
Moped Speciality Shops	30%
Motorcycle Shops and other outlets	25%

Annual Mileage:
    Europe: 2500-3000 miles annually
    U.S.: Insufficient experience

State Regulations:
    More than 30 states separately define mopeds as a separate vehicle; remainder classify as motorcycle

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Sources:
1. Motorized Bicycle Association.
2. Consumer Reports.
3. Mopeds currently sold in the U.S. and tested by EPA
4. Conversations with individual distributors and manufacturers, June, 1980.
5. Dealer News.

the U.S. that are involved to some extent with manufacturing and distributing motorcycle aftermarket products.[3] The majority of these firms are relatively small, young companies. Most have motorcycle-related sales of less than $1 million per year and have been in business less than eight years.

General Aftermarket Company

Firms in the motorcycle aftermarket industry can be classified as manufacturers only, manufacturers and distributors, and distributors only. These companies are not all strictly motorcycle oriented; a significant number are diversified and involved in other industries. For example, some of the motorcycle aftermarket manufacturers are large automotive aftermarket companies which have expanded their operation into the motorcycle market. Some firms also serve the snowmobile, boating, bicycle and other miscellaneous industries. In general, the smaller companies in the industry have a large or complete dependence on motorcycle products sales, and the large companies have a relatively small dependence on motorcycle sales. General characteristics of the aftermarket industry are summarized in Table 2-13.

Exhaust Systems/Components Manufacturers and Distributors

The segment of the aftermarket that will be most directly affected by noise regulation are companies which manufacture exhaust system products - mufflers, exhaust pipes, expansion chambers, and exhaust headers. There are over 150 companies in this group who are selling in a market that is estimated to be slightly over $30 million per year. Most are located in California. Average sales for manufacturing companies are estimated to be approximately $320,000. The leader in the industry is believed to sell between $2 and $3 million worth of exhaust system products per year. Exact distribution of sales in this subsegment of the industry is unavailable but the general nature is evident. The companies are relatively small and compete in a crowded market.

Based on a survey of 11 representative firms, companies in the exhaust system segment of the aftermarket manufactures 2,500 - 40,000 exhaust systems and components per year, have annual sales of $100,000 - $1.1 million, and net 5 to 10 percent profit each year. Market shares range from 1 to 3 percent of the total. Total assets are approximately $300,000, but 60 to 75 percent of these assets are in inventory. Characteristics of exhaust system manufacturers shown in Table 2-14 are derived from manufacturer proprietary information.

Typically the president/owner of the company is also the designer of the exhaust system and components, although one or two people may assist him in this function. Design emphasis is on styling, performance, and sound; the priorities are dependent upon individual company philosophies. Noise

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[3] Motorcycle Dealer News.

Table 2-13

AFTERMARKET INDUSTRY CHARACTERISTICS

- Total motorcycle aftermarket sales*
    - $1.8 Billion
- Number of U.S. aftermarket manufacturers
    - 550 approximately
- Exhaust system aftermarket sales
    - $30,663,000 retail
    - 616,000 purchasers
    - 862,000 exhaust system products
    - $49.73 average per purchase
- Intake system aftermarket sales
    - $5,880,000 retail
    - 840,000 purchasers
    - 1,344,000 units
    - $7.00 average per purchase

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*Ziff-Davis Publishing Co., "Motorcycle Aftermarket Study" - 1974.

Table 2-14

CHARACTERISTICS OF MOTORCYCLE AFTERMARKET EXHAUST SYSTEM MANUFACTURERS*

CATEGORY:	Aftermarket Exhaust System Manufacturer **
NO. OF COMPANIES IN CATEGORY:	90+
LOCATION:	U.S., Predominantly California
PRODUCT LINE:	Mufflers, Expansion Chamber, Headers
TOTAL COMPANY SALES:	$300,000 - $11 Million
ASSETS:	$300,000 ***
NET PROFIT MARGIN:	5 - 10%
NET WORTH:	N/A
TOTAL MOTORCYCLE EXHAUST RELATED SALES	
DOLLARS:	$100,000 - $1.1 Million
UNITS:	2,500 - 40,000
MARKET SHARE:	1 - 3 %
NUMBER OF EMPLOYEES, MOTORCYCLE RELATED:	10 - 40

Source: Information from sample of representative companies.
* 1975
** Most companies derive most or all of their business from exhaust system sales.
*** Generally 60 to 75 percent of assets is in inventories.
N/A - Not Available

control technical capabilities vary from company to company, although most use fairly standard noise control techniques, and the "cut and try" method for design advancements. Research facilities are generally non-existent or very limited.

Estimated market shares replacement parts are presented in Table Non Sequester 2-15 and 2-16.

2.4 Motorcycle Dealers

The major retail outlets in the motorcycle industry are dealers, motorcycle accessory shops, department store chains, discount stores, mail order firms and others (e.g., service stations). Some dealers sell new and used motorcycles, and aftermarket products and services, while other dealers sell aftermarket products only. However, most aftermarket parts and accessory retail sales result primarily from franchised dealers, who are responsible for 75 to 80 percent of total sales (see table below).

SALES OF MOTORCYCLES, PARTS AND ACCESSORIES
BY TYPE OF OUTLET

OUTLET	PERCENTAGE OF TOTAL RETAIL SALES
Franchised Dealerships	75 - 80
Mail Order	10 - 12
Accessory Shops	6 - 8
Department/Discount Stores	6 - 8
Other	1 - 2

Source: Frost and Sullivan, "Motorcycle Original Equipment and Aftermarket Study Announcement," April 1975.

Table 2-15

MANUFACTURERS OF MOTORCYCLE ACCESSORY ITEMS

CURRENT/FUTURE MARKET ANALYSIS*

EXHAUST SYSTEMS

MAJOR BRANDS	CURRENT SHARE OF MARKET PERCENT	FUTURE SHARE OF MARKET PERCENT
Honda	21.0	11.0
Hooker	13.0	30.0
Yamaha	5.0	-
Suzuki	4.0	-
Torque	4.0	9.0
Bassani	3.0	7.5
Dunstall	2.0	1.5
Kawasaki	1.5	-
Rupp	.5	-
All others	46.0	41.0

Table 2-16

EXPANSION CHAMBERS*

MAJOR BRANDS	CURRENT SHARE OF MARKET PERCENT	FUTURE SHARE OF MARKET PERCENT
Hooker	22	32
Bassani	20	26
Yamaha	8	3.5
Suzuki	4	-
J & R	3	3.5
Kawasaki	2	2.0
Honda	2	-
All others	39	33

---

* 1975 Motorcycle Market Study, Power - Robertson & Company

There are an estimated 7,900 independent franchised dealers in the U.S. selling motorcycles and aftermarket products and services. Most carry one brand of motorcycle exclusively, although a significant number carry more than one brand. Multiple brand representation is generally only for motorcycle manufacturers that offer a small specialized product line; the typical multiple brand dealer represents more than one of these manufacturers to expand the variety of models he can sells. Estimated 1977 U.S. retail sales by franchised motorcycle dealers is $3.4 billion dollars. A further breakdown is shown in Table 2-17.

Table 2-17

ESTIMATED 1977 U.S. RETAIL SALES BY FRANCHISED MOTORCYCLE DEALERS

New Motorcycle Sales	$1.49 billion
Used Motorcycle Sales	.37 billion
Accessory Sales	.44 billion
Service Sales	.43 billion
Parts Sales	.47 billion
Other	.20 billion
TOTAL	$3.40 billion

Source: Motorcycle Dealer News, 1978.

Nearly 44 percent of dealer sales are generated from new motorcycle sales, while accessories, parts and services sales make up almost 40 percent. The breakdown is as follows:

New Motorcycle Sales	43.8%
Used Motorcycle Sales	10.9%
Accessories	12.9%
Parts	13.9%
Service	12.5%
Other	6.0%

Source: Motorcycle Dealer News, 1978.

Average annual sales for motorcycle dealers is approximately $360,000. Approximately 50 percent of the dealers are in the $100,000 - $499,000 sales range.

The typical dealer has a relatively small profit margin (3 percent before taxes), and relies heavily on short term financing for his inventory. Interest expense becomes critical when sales decrease for dealers with large inventories. Such dealers are forced to discount their prices, thereby reducing their profit margin even more. This process is especially crucial to the smaller dealers who are generally undercapitalized and have a low sales volume to support their operations.

2.5 Total U.S. Motorcycle Industry Employment

Total U.S. motorcycle industry employment is shown as follows:

Table 2-18

ESTIMATED U.S. MOTORCYCLE INDUSTRY EMPLOYMENT*

INDUSTRY SEGMENT	NUMBER OF EMPLOYEES	SOURCE
New Motorcycle Manufacturers and Distributors	5,600	1
Aftermarket Manufacturers	12,000**	2
Franchised Dealerships	35,000	2,3
Other Retail Outlets	5,000	4
Miscellaneous	2,000	
TOTAL	59,600	

Data derived from following sources:
(1) Information from various companies.
(2) Motorcycle Dealer News.
(3) Motorcycle Industry Council.
(4) Energy and Environmental Analysis, Inc., "Economic Assessment of Motorcycle Exhaust Emission Regulations".
* 1975
** 1200 in aftermarket exhaust system manufacturing.

2.6 Motorcycle Warranties

Street motorcycles are often warranted against defects in materials and assembly for six months and a corresponding distance of travel. Shorter warranties (three months) and longer ones (one year) are also known. Off-road motorcycles are often warranted for three or six months, although semi-competition models and strictly competition motorcycles often have no warranty. To EPA's knowledge formal warranties are extended on very few replacement exhaust systems, although many manufacturers will repair or replace products that are obviously defective.

SECTION 3

NOISE LEVEL TEST PROCEDURES

SECTION 3

NOISE LEVEL TEST PROCEDURES

3.1 Application and Criteria

Existing noise test methodologies which have been either adopted, approved, or proposed in the United States or in other countries were examined for possible use in the EPA regulation. Several criteria were established to review these procedures and to provide a basis for possible refinement.

Ideally, a noise measurement procedure for new motorcycles should:

(a) Characterize the noise as perceived at the wayside in terms that relate to the adverse impact on humans.

(b) Characterize the noise during the most annoying mode(s) of operation commonly encountered in areas of impact.

(c) Measure noise levels on a comparable basis for all motorcycles in specified categories, as measured in the operating mode(s) identified above.

(d) To the extent possible, satisfy several practical requirements. Specifically, a testing procedure should be:

(1) Clear and easily understandable.

(2) Repeatable with a minimum of variation.

(3) Capable of being conducted with a minimum of meteorological and site-to-site variability.

(4) Insensitive to configuration options (such as gearing, sprocket ratios) which can result in variations of measured noise disproportionate to actual variations in vehicle noise.

(5) Free from ambiguous procedural situations requiring determinations which can affect the measured noise level.

(6) Minimally influenced by factors affecting vehicle performance, such as atmospheric conditions, rider weight, accessories, etc.

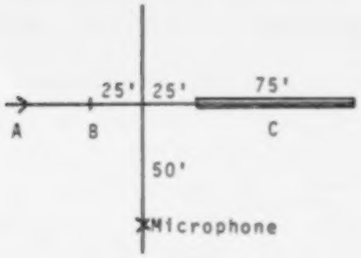
None of the existing in-use or proposed procedures, in their present form, satisfied the above criteria to the extent desirable in the intended applications. Accordingly, variations of these procedures designed to eliminate certain shortcomings of the existing procedures were explored. A description and critique of each procedure appears on the following pages.

3.2 Moving Vehicle Test Procedures

SAE J331a (Moving vehicle acceleration test)

This test method, or variations of it, is the most commonly used noise measurement procedure for motorcycles sold in the U.S., and is the method for which the largest data base currently exists. It was therefore the baseline method to which other candidate procedures were compared. The procedure consists of approaching a marker at 30 mph or 60 percent of maximum rated RPM[1] (whichever is slower), accelerating at full throttle commencing at a point 25' before the microphone, and closing the throttle at a point 100' past the microphone, or when maximum rated RPM is reached (whichever occurs earlier). Second gear is used unless the vehicle travels less than 50' before reaching maximum rated RPM, in which case third gear is used. Six measurements on each side are taken, the highest and lowest discarded, and the reported level is the average of four readings within 2 dB (A-weighted) of each other on the loudest side.

The full text of the procedure is in Appendix A.



A. Approach at 30 mph or 60% RPM (the slower).

B. Accelerate in 2nd gear unless 100% RPM reached before zone C, in which case use 3rd gear.

C. Close throttle at 100% RPM or at end of zone C (the earlier).

Critique:

(a) The highest noise level achieved during a given test occurs at different distances from the microphone for different motorcycles. This means that for some motorcycles the highest noise level is measured, while for others the measured level could be substantially less than the maximum. This variable is influenced by horsepower, gear ratio and sprocket ratios. Data on distance variability are presented in Appendix C, Table C-11. To a certain extent, this variability accounts for the differences in normal operation of high and low powered motorcycles. However, it also results in significant difference in measured levels among motorcycles having almost identical characteristics.

(b) Some motorcycles, particularly the larger vehicles, do not reach maximum rated RPM. In such cases, not only is maximum noise not developed, but also, the highest noise level generated is at a point where the vehicle is furthest from the microphone. Data on percent RPM attained are also in Appendix C, Table C-11.

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[1] As used in this document, "maximum rated RPM" means the engine speed at which "peak brake power" (as defined in SAE J245) is achieved. Percent rpm is in reference to maximum rated RPM as 100%.

(c) Due to vehicle and test variables, motorcycles of the same make and model are not necessarily tested in the same gear. This could result in a situation where a motorcycle was tested by the manufacturer using one gear, and verified by a government agency using a different gear. The measured levels could be substantially different in the two cases.

(d) Different size sprockets are available as options on most motorcycles, and are readily interchanged by the user. The 50 foot minimum distance criterion makes the SAE J331a test sensitive to sprocket ratio. Thus, the manufacturer could select a sprocket ratio which gives most favorable results under this procedure, and supply to the user other sprockets for various use applications. The practice of changing sprockets is widespread, particularly in off-road or combination street/off-road motorcycles. The important point here is that changing sprockets does not necessarily affect substantially the actual generated noise, but can have major effect on the measured level in the SAE J331a test.

(e) The procedure does not provide for the testing of motorcycles with automatic transmissions.

(f) The procedure does not provide for the situation when, even in 3rd gear, the vehicle does not travel the stipulated distance.

(g) Atmospheric conditions which affect power output will affect closing RPM and/or vehicle position in relation to the microphone (in addition to affecting sound power generated).

(h) Vehicle closing conditions (RPM and/or position) are affected by rider weight, accessories weight, wind, and wind resistance.

(i) This test procedure has the advantage of being independent of tachometer dynamic characteristics for larger motorcycles (approximately 400-500 cc).

CHP Variation of the SAE J331a (Moving vehicle acceleration test)

The California Highway Patrol (CHP) adopted the SAE J331a method for type approval, with two variations:

(a) If maximum rated RPM is reached before 30 mph, or if a 50 foot acceleration distance is not attained, the next higher gear is to be used. (Other stipulations of SAE J331a apply.)

(b) Four instead of six measurements are required on each side of the vehicle and the average of the two highest readings (within 2 dB of each other) on the loudest side are reported.

States which have adopted the CHP method are California, Colorado, Floria and Oregon. States and cities which have adopted the SAE J331a method are Maryland, Washington, Grand Rapids, Chicago and Detroit (Detroit requires only two measurements on each side of the vehicle).

The full text of this procedure is in Appendix A.

Critique:

(a) Variation "a", above, will primarily affect the smaller motorcycles, obviates certain test operation difficulties that may result in over-reving, and may be more representative of operational conditions for these vehicles. Variation "b", based on test experience with measurement consistency, should have no significant effect, and results in a simpler test procedure.

(b) The other shortcomings identified in the SAE J331a procedure critique remain in the CHP variation of SAE J331a.

SAE J986a (Moving vehicle acceleration test)

The SAE J986a procedure, although designed for passenger cars and light trucks, is prescribed in Canada for the testing of motorcycles.

Major differences, referred to SAE J331a, are:

(a) Approach is at 30 mph in all cases.

(b) Sole criterion for gear selection is that the lowest gear which will achieve the 50 foot acceleration distance shall be used.

(c) The end-zone is 100 ft. long, instead of 75 ft.

Full text of the procedure is presented in Appendix A.

Critique:

(a) The speed and gear selection stipulations are not suited to some motorcycles.

(b) The gear selection stipulation will result in full acceleration in 1st gear for the larger motorcycles, with possible hazard to the operator.

SAE J47 (Moving vehicle acceleration test)

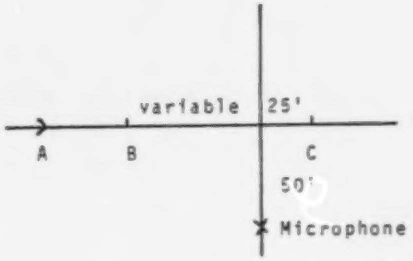
The SAE J47 procedure was designed to measure the maximum noise potential of the vehicle. It differs from the SAE J331a procedure in the following major respects:

(a) Instead of a variable end-point, a variable acceleration start-point is employed, such that all vehicles reach maximum rated RPM at a point 25 feet past the microphone.

(b) The gear employed is the lowest gear that does not result in an accelerating distance of less than 50 feet (for many motorcycles, this will be first gear); however, when the above selected gear "results in a dangerous or unusual operating condition such as wheel spin, front wheel lifting, or other unsafe conditions, the next higher gear shall be selected...."

(c) Approach to the acceleration point is made at 60 percent of maximum rated RPM in all cases.

The reporting method is the same as SAE J331a. The full text is in Appendix A.



A. Approach at 60% RPM.

B. Accelerate in lowest gear such that BC is not less than 50'. If this results in unsafe condition, use next higher gear. By trial, point B is selected such that maximum rated RPM is reached at point C.

C. Close throttle at end point C, 25' past microphone point.

Critique:

(a) The SAE J47 test provides a more consistent measure of maximum noise level, since all vehicles reach maximum rated RPM at the same point in relation to the microphone.

(b) Since the above condition does not prevail in the SAE J331a test, correlation between the two procedures cannot be expected, although maximum differences by motorcycle category may be developed.

(c) As with SAE J331a, motorcycles of the same make and model are not necessarily tested in the same gear (due to vehicle and test variables). Gear selection is further based on a judgment as to whether operation in that gear is safe or not. However, in the SAE J47 test the particular gear used is of secondary importance, since in this test all motorcycles reach maximum rated RPM at full throttle, and reach this condition at the same point in relation to the microphone. The effect of gear selection on measured levels was investigated during this study, with test results presented in Table 3-1 (F-76 procedure description).

(d) Since in the SAE J47 test gear selection is of only secondary significance in relation to measured levels, the matter of sprocket options (discussed in critique of SAE J331a) is also not critical.

(e) The safety aspects of the SAE J47 testing procedure are such as to require a skilled rider familiar with the behavior of the particular motorcycle, and exercise of care in its operation.

(f) The procedure is less sensitive to factors affecting vehicle performance than is the SAE J331a.

(g) The method has potential for precise correlation with a stationary vehicle dynamometer test, since power output together with position in relation to the microphone are defined.

The noise control regulations of Italy incorporate a noise test procedure which in essence is the SAE J47. Approach conditions are not prescribed, the only stipulations being that 1st gear shall be used and that the vehicle shall develop rated power and RPM when the vehicle is at the microphone target point. Substitute methods of engine loading are permitted, such as grade or dynamometer.

ISO/R-362 (Moving vehicle acceleration test)

The International Standards Organization, (ISO) Recommendation R-362, "Measurement of Noise Emitted by Vehicles", was approved in May 1962 by the following ISO Member Bodies[2].

Australia
Austria
Belgium
Brazil
Canada
Chile
Czecholovakia
Denmark
Finland
France
Germany
Greece
Hungary
India
Ireland
Israel
Netherlands
New Zealand
Poland
Portugal
Spain
Sweden
Switzerland
United Kingdom
U.S.A.
U.S.S.R.
Yugoslavia

The ISO/R-362 moving vehicle test procedure has since been incorporated into the regulations of the following countries:

France
Luxemburg
Netherlands
Norway
Portugal
Austria
United Kingdom
West Germany

Japan and Belgium have adopted a variation of the ISO/R-362 method. The Economic Commission for Europe (ECE) has adopted the ISO/R-362 method and has prescribed noise standards for various categories of motorcycles. Sweden and Australia have proposed revisions to the ISO/R-362.

In the test, approach is made at 75 percent rpm for peak power or 50 km/h, (whichever is slower). 2nd Gear is used if the vehicle is fitted with a two-, three-, or four-speed gear box. If the vehicle has more than four speeds, 3rd gear is used. The throttle is fully opened at a point 10 m before the microphone point, and closed 10 m past the microphone point.

Provisions are included for the testing of vehicles with no gear box, and for vehicles with automatic transmission.

Two readings within 2 dB of each other are required on each side of the vehicles, and the highest value reported.

Full text of the procedure is in Appendix A.

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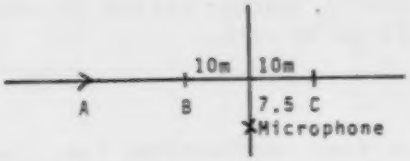
[2] "Approved" does not necessarily mean adoption into the regulations of that country.



A. Approach at 75% rpm or 50 km/h, whichever is slower.

B. Accelerate in 2nd gear for vehicles having up to four speeds, 3rd gear for vehicles having five or more speeds.

C. Close throttle.

Critique:

(a) The test is simple, and subjective determination of proper gear selection has been eliminated.

(b) A technical advantage is that acceleration termination is based on vehicle position, not RPM, thus eliminating errors in closing RPM reading or tachometer lag.

(c) The test was designed to be related to "normal town driving conditions".

(d) Peak power will be developed on some vehicles, but not on others; therefore, maximum noise level will be measured on some motorcycles, not on others.

(e) The problem associated with sprocket options, as discussed in critique of the SAE J331a procedure, is viewed as critical, and is not addressed.

(f) Some off-road motorcycles are geared sufficiently low that they will not travel the required 20 meters in the stipulated gear without exceeding maximum rated RPM.

(g) To meet their special requirements, or to eliminate certain problems encountered with the ISO/R-362 procedure, various countries have adopted or proposed modifications to the basic procedure. These are discussed below.

ISO/R-362 Variations (Moving vehicle acceleration tests)

"Modified Method", Appendix A2 to ISO/R-362-1964:

In this variation, the gear is selected which most closely results in a vehicle speed of 50 km/h at 75 percent RPM, and approach is made at 75 percent RPM. It is further stipulated that if the vehicle has more than three speeds, first gear shall not be used.

"ISO/R-362 Proposed Amendment", 1974:

In this variation, approach is at 75 percent RPM or 50 km/h (whichever is slower), except that if the speed corresponding to 50 percent RPM is less than 50 km/h, then entry shall be at the speed corresponding to 50 percent RPM. 2nd gear is to be used, unless 100 percent RPM is reached before the end of the acceleration zone, in which case 3rd gear is to be used.

JASO Modification of ISO/R-362:

This variation of the ISO/R-362 procedure has been incorporated into the regulations of Japan and Belgium. Modifications to the basic ISO/R-362 are in gear selection and approach speed:

	JASO*	ISO/R-362
Gear Selection	2nd gear: 2, 3-speed gear box 3rd gear: 4-speed gear box 4th gear: over 4-speed gear box	2nd gear: 2, 3, 4-speed gear box 3rd gear: over 4-speed gear box
Approach Speed	25 km/h: under 50 cc 40 km/h: 50-249 cc 50 km/h: 250 cc & over (or 75% RPM)	50 km/h (or 75% RPM)

"Second Draft Proposal", Revision of ISO/R-362, May, 1975:

Major revisions, referred to the ISO/R-362 procedure are:

(a) Vehicles having gear boxes of five or more speeds are to be tested in both 2nd and 3rd gears, and the reported value is to be arithmetic average of the two measurements.

(b) The procedure for testing vehicles with automatic transmissions is revised and expanded.

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* Japanese Acoustical Standards Organization

Critique:

(a) The numerous variations of ISO/R-362, dealing mainly with approach speed and gear selection, reflect the difficulty with this type of test (where approach conditions, but not termination conditions, are controlled) in arriving at a procedure that adequately characterizes the noise of a broad range of motorcycles.

(b) A very comprehensive study [3] of motorcycle noise and test procedures conducted in Japan compared noise emissions of a group of motorcycles as measured by three variations of the ISO/R-362 procedure (JASO, ISO, ISO Proposed Amendment). These variations, differing only in approach speed and gear selection, yielded measured noise level variations up to 12 dB, showing the criticality of these parameters on measured levels. This also indicates that a change in sprocket ratio will result in a change in measured noise level. (The Japanese investigators determined that the JASO modification of the ISO/R-362 procedure yielded the best correspondence with average noise due to average acceleration, as related to Japanese urban traffic situations.)

F-76 (Moving vehicle acceleration test)

While all of the above test procedures are considered to be candidates for use in the final EPA regulations, all of these procedures were found to have shortcomings as a methodology for the Federal regulations. These shortcomings fall in one or more of the following areas:

(a) Safety; hazard in testing (SAE J47)

(b) Ambiguity; measured level dependent on gear selection involving a subjective determination (SAE J331a)

(c) Sprocket variables; measured level dependent on sprocket ratio which is readily changeable; change in measured level disproportionate to change in vehicle noise (SAE J331a, ISO/R-362)

(d) Position variables: similar vehicles, differing only in gearing, having noise measured at different distances from the microphone, or at different RPM and power conditions (SAE J331a, ISO/R-362)

(e) Performance variables: atmospheric conditions, rider weight, or accessories affecting vehicle closing RPM and/or position (SAE J331a, ISO/R-362).

Representatives of the U.S. Suzuki Motor Corporation and the California Highway Patrol, submitted preliminary drafts of test procedures designed to eliminate the above objections. These procedures, together with other procedures, were evaluated and refined. The resulting procedure has been designated F-76, and consists of the following:

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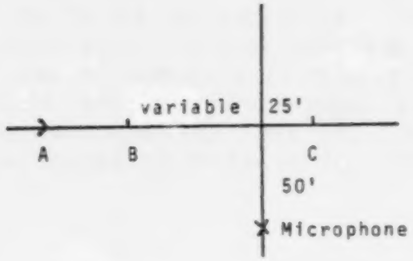
[3] See page 3-40.

Approach is made at 50 percent of maximum rated RPM. The throttle is smoothly and fully opened, commencing at a point such that 75 percent of maximum rated RPM at full throttle is reached at a point 25 feet past the microphone target point, at which time the throttle is closed. Second gear is used, unless the accelerating distance is less than 25 feet, in which case progressively higher gears are used until the minimum 25 feet distance is attained. It is further specified that if use of second gear results in a road speed in excess of 100 km/h (62 mph), then first gear shall be used.

Full text of the procedure is in Appendix A.



A. Approach at 50% RPM.

B. Accelerate in 2nd gear from point B, selected such that 75% RPM is reached at point C. If BC is less than 25', use next higher gear. If speed at C is more than 62 mph, use 1st gear.

C. Close throttle.

Critique:

(a) Safety. The procedure does not require rapid opening of the throttle; mandatory requirement is that wide open throttle at 75 percent RPM be attained 25 feet past the microphone. No instances have been encountered in EPA's test program where use of first gear was required; in any case, use of first gear would not be hazardous under the prescribed operation of the throttle.

The procedure results in many off-road motorcycles being tested in third, and even fourth gear. Even in these higher gears, many off-road motorcycles will exhibit front wheel lift-off under rapid throttle opening. Although the procedure does not require such. Lift-off, however, is not hazardous with these vehicles when operated by an experienced rider; it is, in fact, a normal operational mode, used widely in the traverse of obstacles in rough terrain.

(b) Ambiguity. Tests that were conducted show that procedures which call for attainment of a specified condition of power and RPM at a specified location in relation to the microphone (such as SAE J47, F-76), are relatively insensitive to gear selection (Table 3-1).

(c) Sprocket variables. The relative insensitivity to gear selection in the F-76 test shows that a change in sprocket ratio will have little effect on measured noise levels.

Table 3-1

EFFECT OF GEAR SELECTION ON MEASURED NOISE LEVELS

Bike No.	Category	Displ.	SAE J331a	F76	SAE J47
101	S	356		-0.2 -1.3	
103	SX	123			
109	X	248	-5.5		
119	S	398		-1.7	
126	S	184		-0.3	
123	SX	249			
127	S	738			
130	SX	98	-3.2		
131	S	371			
132	S	543			
134	S	246			
135	SX	173	-1.6		
146	X	246			
*151	S	949	-1.7		
153	X	248			
155	SX	98	-0.9		
*160	S	736	-3.7		
161	SX	247	-1.1		
*166	SX	72	-2.6		
173	SX	397	-1.7		
181	SX	183	-3.3		
191	SX		-1.3		
197	SX	242	-4.0		

(d) Position variables. In the F-76 test, the noise level, at the specified power and RPM conditions, is always measured at the same distance from the vehicle.

(e) Performance variables. As with the other test procedures, the measured level in the F-76 procedure will be affected by factors which affect sound power (such as relative air density); correction factors could be applied for this. In contrast with the SAE J331a procedure, however, the F-76 measured level is not affected by RPM/distance relationships associated with variations in power output.

(f) Methodology substitution. Since the F-76 test is conducted under controlled conditions of power, RPM, and measurement distance, it can be deduced that the means used to load the engine are relatively unimportant. For example, the same result should be obtained on a grade, or on a suitable dynamometer, as long as the prescribed end-conditions are attained. (The Italian procedure, which is similar to the SAE J47, permits these substitutions in lieu of the prescribed acceleration test). In contrast, procedures such as the SAE J331a or the ISO/R-362 offer no possibility of such substitutions as equivalents.

(g) Tachometers. Tachometer lag time can have an important effect on the noise levels measured by F-76. Slow-responding tachometers will indicate engine speeds higher than those specified in the procedure 25 feet past the microphone point. These higher engine speeds will result in erroneously high noise level measurements.

While it is possible to derive a statistical transfer function between F-76 and SAE J331a (as has been done in section 4) it is not possible to predict, for a particular motorcycle, the F-76 level based on the SAE J331a level using this transfer function. The reasons for this are fundamental. For the smaller motorcycles, the SAE J331a level is dependent of where in the end-zone the vehicle reaches 100 percent RPM. If it reaches 100 percent RPM near the start of the end-zone, the F-76 level (75 percent RPM) will be lower; if it reaches it near the end of the end-zone, the two levels will be about equal (differences in power being cancelled by differences in distance). This in turn depends on gearing, and on which gear is used. In the case of the larger machines, the degree of equivalence is dependent on the value of the SAE J331a closing RPM. If the closing RPM is at a near 100 percent, the two levels will be near equal; if the closing RPM is well below 100 percent, the F-76 level will be higher. By making use of these factors, together with vehicle performance data, it would be possible to estimate F-76 levels for a particular motorcycle, based on the SAE J331a level.

For the above reasons, no close correlation should be expected between the F-76 levels and SAE J331a levels. It was considered of interest, nevertheless, to examine the degree of correlation, which is shown in Figures 3-1 and 3-2. The relatively good correlation in the case of the off-road motorcycles is no doubt attributable to the fact that most of these are small displacement, low-geared machines, and therefore reach the acceleration end point near the microphone in both test procedures.

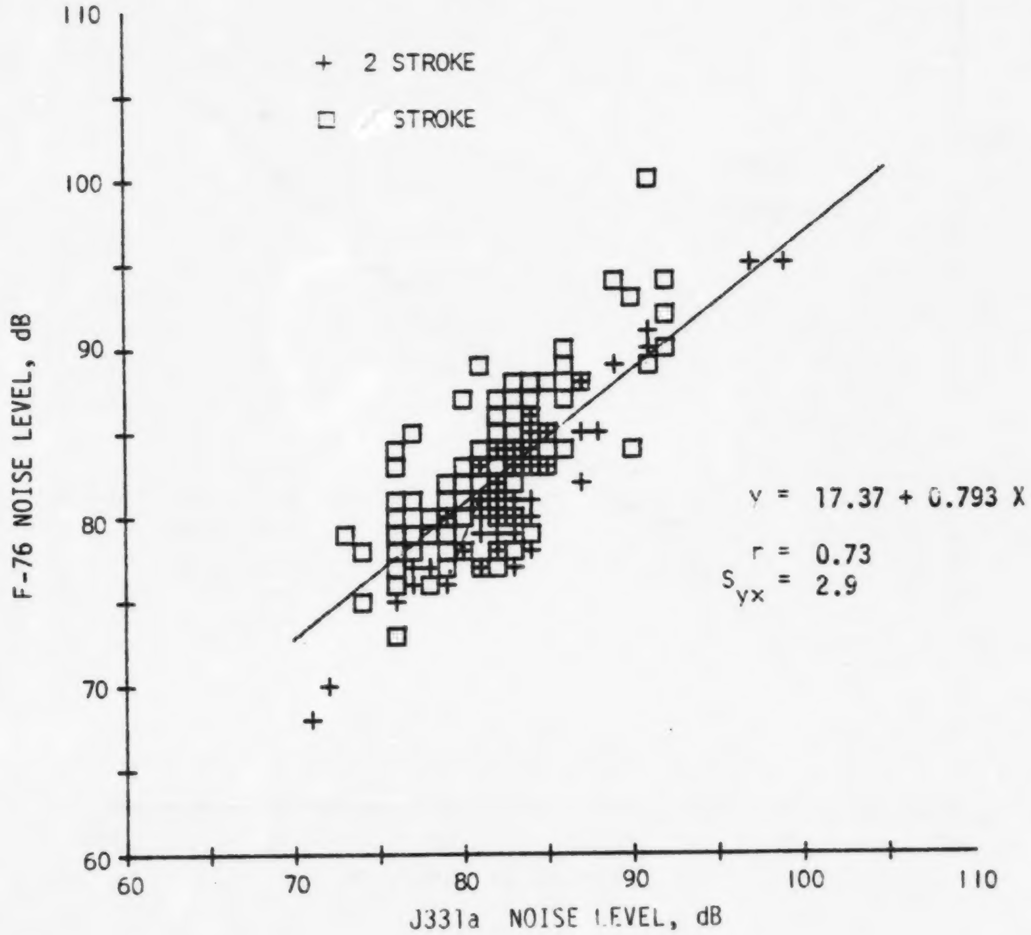


FIGURE 3-1 CORRELATION BETWEEN F-76 AND J-3
STREET AND COMBINATION STREET/OFF-ROAD
1975-1976 YEAR OF MOTORCYCLE MANUFACTURE

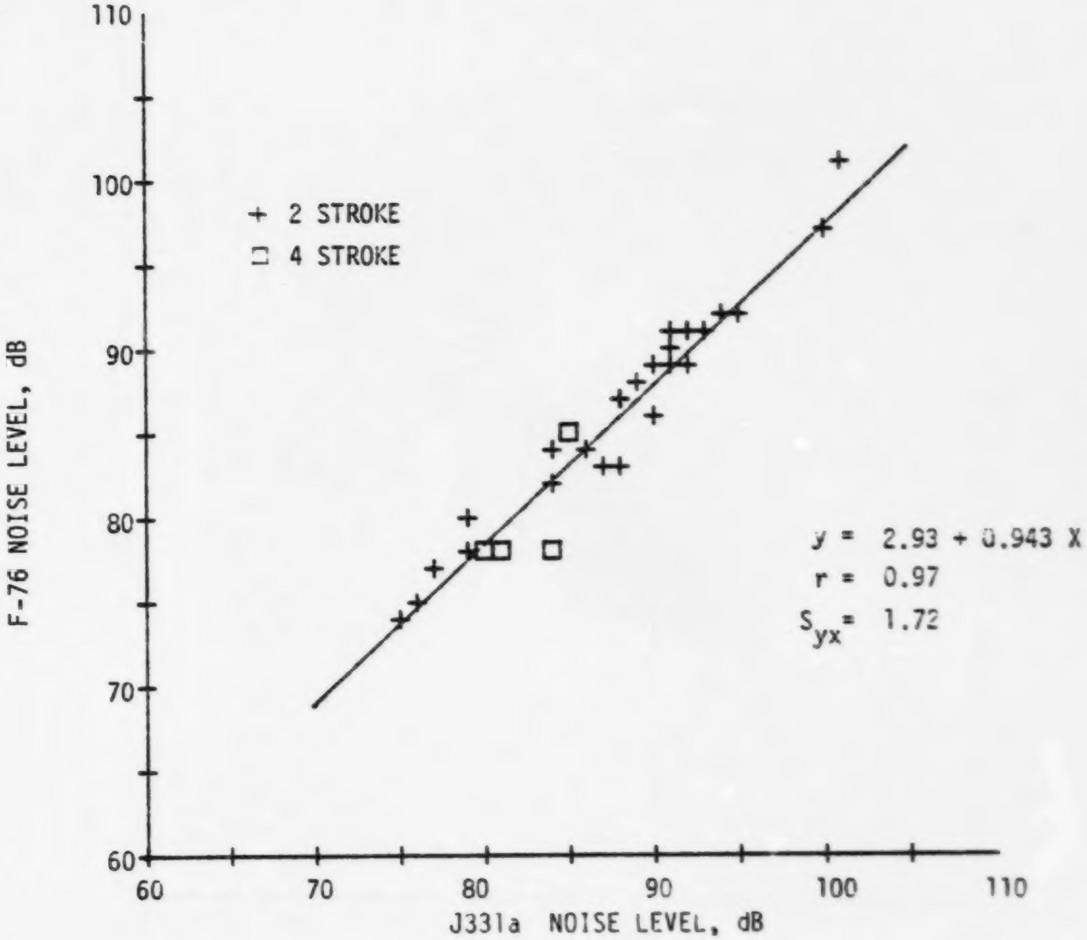


FIGURE 3-2 CORRELATION BETWEEN F-76 and J-331a TESTS,
OFF-ROAD (ONLY)
1975-1976 YEAR OF MOTORCYCLE MANUFACTURE

Note: In the initial drafts of this procedure, a 50 ft. minimum acceleration distance was stipulated and employed. Difficulties occurred in two areas--several of the smaller bikes could not attain the 50 ft. distance before reaching 75 percent RPM even in the highest gear; others (350 cc class off-road bikes) would not pull properly from 50 percent RPM in the gear required to attain the 50 ft. distance. For these reasons the 50 ft. minimum acceleration distance was changed (starting with bike No. 135 refer to Table 3-1) to 25 feet. The 25 ft. minimum distance stipulation presented no problems in the testing of any of the motorcycles.

F-76a (Moving vehicle acceleration test)

In examining the noise emission data base (Section 4), in terms of SAE J331a levels (Figure 4-1)[4], and in terms of F-76 levels (Figure 4-3)[4], the SAE J331a method yields a regression line nearly flat (noise level independent of displacement), whereas the F-76 method shows a definite upward slope of the regression line with engine displacement.

The reason for this is, of course, that in the SAE J331a test the larger motorcycles pass through the measurement zone without reaching maximum rated power RPM, whereas in the F-76 test all vehicles are measured at 75 percent RPM. The ISO/R-362 test is similar to the SAE J331a test and recognizes the fact that both in constant speed and in accelerating modes the smaller machines will usually be operated closer to their maximum potential than will the larger machines. This is not only because of available horsepower, but also, in the small machines the torque curve is characteristically steep, favoring operation at high RPM. In the large street machines the torque curve is relatively flat, resulting in acceptable performance at lower rpm's.

To take this factor into account, a variation of the F-76 method, designated F-76a, was investigated. The F-76a procedure differs from the F-76, in that instead of testing all vehicles at 75 percent RPM, the test RMP is a function of displacement. The RPM/displacement relationship follows:

$y = 90\%$ at (0-100 cc) where y is % RPM

$y = 95\%$ $.05x$ at (100-700 cc) x is displacement, cc

$y = 60\%$ at (700+ cc)

This relationship, shown graphically in Figure 3-3, yields a test RPM of 90 percent at 100 cc, reducing to 60 percent at 700 cc. Above 700 cc the closing RPM remains constant at 60 percent. Entering RPM is 50 percent or 20 percentage points below closing RPM, whichever is lower.

The basis of the F-76a RPM/displacement relationship is the data collected in the course of EPA's test program where a number of motorcycles were tested at more than one closing RPM. These data appear in Appendix C and in Tables C-11 and C-12, and are summarized in Table 3-2 and Figure 3-4 in this Section.

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[4] Figures pertaining to the noise emission data base are presented in Section 4.

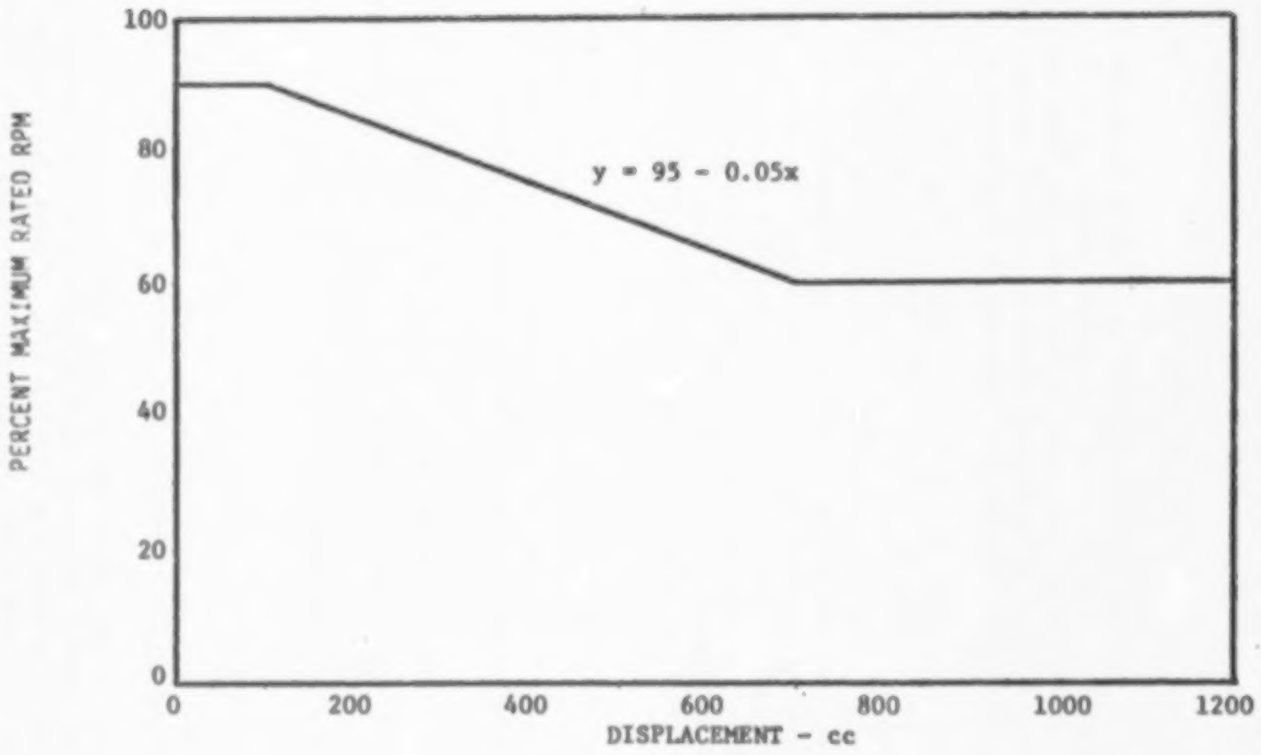

FIGURE 3-3 CLOSING RPM FOR F76a MOVING VEHICLE ACCELERATION TEST

TABLE 3-2. COMPARISON OF F-76a AND SAEJ331a NOISE LEVELS

Displacement Range cc	Mean Noise Level, dB F76a	Mean Noise Level, dB SAE J331a	Standard Deviation F76a	Standard Deviation SAE J331a	Number of Vehicles in Sample
100 - 125	80.8	80.9	2.57	2.62	10
175 - 250	80.8	80.9	1.73	2.34	8
350 - 400	82.5	81.1	1.77	3.55	6
550 - 750	82.3	81.9	1.38	0.71	6
900 - 1200	82.6*	80.6	1.91	3.58	4

The vehicles in this sample are unmodified, 1975 - 1976 year of manufacturer, street and combination street/off-road motorcycles. The F-76a levels have been derived by interpolation or extrapolation of noise levels measured at RPM other than the F-76a RPM. The SAE J331a levels are directly measured data.

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*This small sample of 4 included two vehicles whose F-76 level was considerably higher than the average of other vehicles in this category.

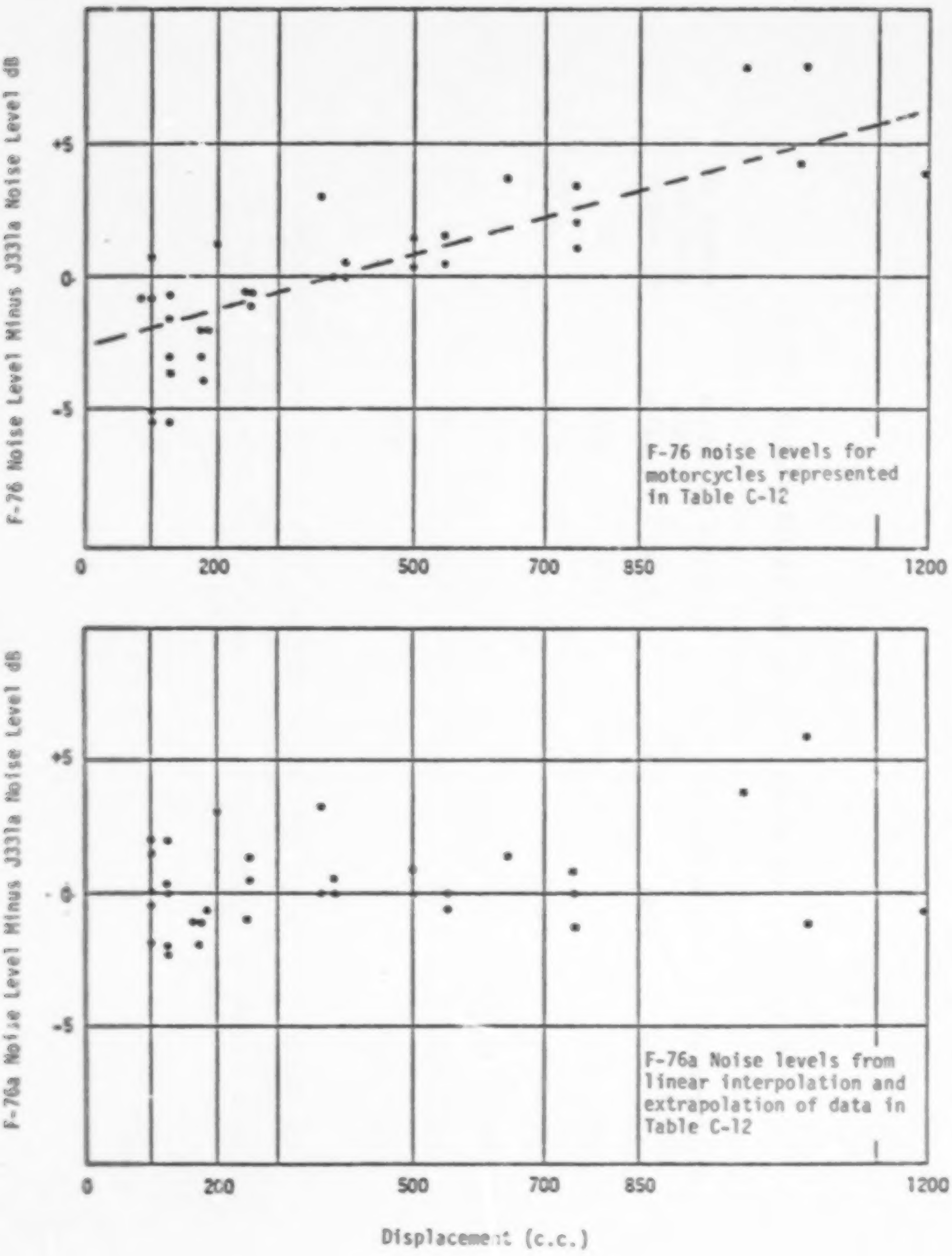

FIGURE 3-4 COMPARISON OF F76 AND F-76a NOISE LEVELS

Figure 4-5[5] shows the difference between F-76 and SAE J331a levels plotted against displacement, with the upward sloping regression line showing that statistically the F-76 level is higher than the SAE J331a level for large motorcycles, lower for small motorcycles. Table 3-2, shows that while a larger statistical sample of F-76a test data is desirable, the data indicate that if F-76a data were substituted for F-76 data, the regression line would not only be independent of displacement, but would also be approximately equal to the SAE J331a levels on a statistical basis.

A curve of noise level versus percent RPM for one motorcycle is shown in Figure 3-5.

A secondary advantage of the F-76a procedure over F-76 is that lower testing speeds result for the large motorcycles. In the F-76 test, speeds up to 55 mph were encountered. This would reduce be about 45 mph in the F-76a test. Manufacturer test data show tire noise of 66 dB at 45 mph on a 750 cc motorcycle, which indicates that tire noise would not be a significant contributor to total vehicle noise in the F-76a test.

Text of the F-76a procedure is in Appendix A.

R-60 (Moving vehicle acceleration test)

With the same rationale basic to the F-76a test, a staff member of AMF Harley-Davidson submitted (prior to development of the F-76a test) a moving vehicle acceleration test procedure designated R-60. The R-60 test is similar to the F-76a except that the closing RPM is the RPM corresponding to 60 mph in the highest gear (instead of 75 percent RPM for all vehicles). Entering RPM is 75 percent of the closing RPM.

A full text of the procedure is presented in Appendix A.

Critique:

(a) The procedure does not provide for the testing of vehicles which do not reach 60 mph; this difficulty could be eliminated by adding the stipulation that vehicles which reach 100 percent RPM before 60 mph shall be tested at 100 percent RPM.

(b) Similar vehicles, differing only in gearing, could be tested at substantially different RPM's yielding substantially different measured levels.

(c) Changing sprockets would result in testing at different RPM's, with different measured levels.

(d) Some street motorcycles are capable of very high speeds. A motorcycle with a top speed of 135 mph would be tested at 44 percent RPM, a rather low test RPM.

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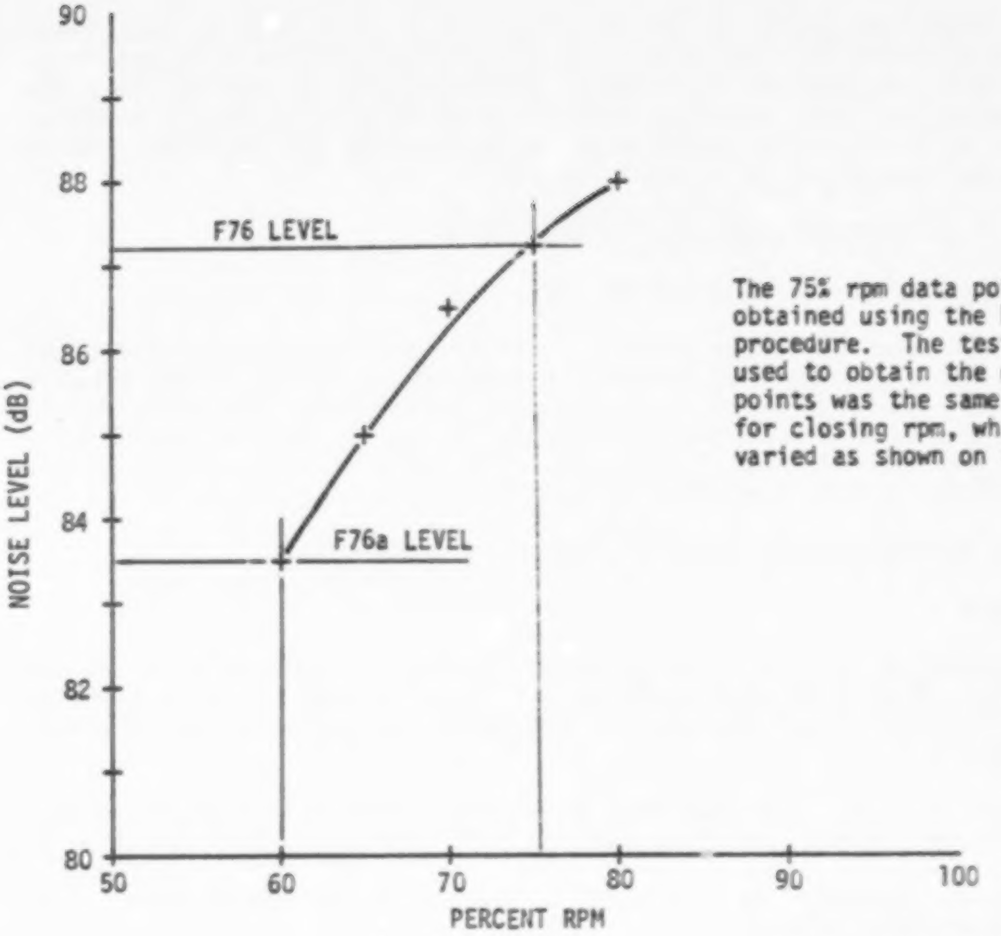
[5] Figures pertaining to the noise emission data base are presented in Section 4.



The 75% rpm data point was obtained using the F76 test procedure. The test procedure used to obtain the other data points was the same except for closing rpm, which was varied as shown on the plot.

FIGURE 3-5 EXAMPLE OF NOISE LEVEL AS A FUNCTION OF PERCENT RPM (HARLEY XLH-1000)

(e) The F-76a procedure provides an alternative means of dealing with the different operational situations of the small and large machines, and avoids the difficulties appearing in the R-60 method.

F-77 (Full speed, full throttle, moving vehicle test)

In lieu of the ISO/R-362 acceleration test, Norway prescribes a full speed, full throttle pass-by test for mopeds. In the course of the study, this procedure was examined for motorcycles up to 100 cc; above that some vehicles reach excessive speeds.

This is a considerably simpler test to run than any of the other moving vehicle procedures, requires no tachometer or speedometer, and is representative of common operational conditions for vehicles under-100 cc. It yields levels usually close to the SAE J331a levels, and can be expected to yield levels close to the F-76a test.

Full text of the procedure is in Appendix A.

Problem Areas: Moving Vehicle Test Procedures

(1) Automatic Transmissions

Automatic transmissions are coming into use for both street and off-road motorcycles, large and small. The following motorcycles with automatic transmissions were tested:

Street

Moto Guzzi V1000 Converter
Honda CB750A
Honda NC-50

Off-Road

Rokon 340 RT
Husqvarna 360 Automatic

Combination Street/Off-Road

Yamaha Chappy (minibike)

Mopeds

NTV Model ERB
Kreidler MP3
Vespa Ciao
Motobecane Mobylette
Velosolex 4600
Peugeot 103LVS.U3

Difficulty was encountered in testing the motorcycles with automatic transmissions. The Moto Guzzi V1000 and the Honda CB750a incorporate a high and low-range selection; low range produces significantly higher levels for the SAE J331a test. High-range use for the F-76 test results in excessive speed. For the F-77 test, however, high-range can cause the engine to over-rev unless it is specified.

The Rokon 340RT and the Husqvarna 360 Automatic also presented testing problems. The Rokon 340RT incorporates a variable ratio belt drive; the driving member is acted upon by centrifugal forces, the driven member is affected by reacting torque. The drive ratio is determined by both engine rpm and torque demands. There are no selectable options for the rider, other than throttle position. The SAE J331a test procedure, does not provide for the testing of vehicles with automatic transmissions. However, if the gear stipulation is ignored, a meaningful SAE J331a test can be run. To run an F-76 test, however, an entirely different technique is required: the throttle must be opened very gradually in order not to immediately exceed 75 percent RPM; with some practice, vehicle speed can be smoothly increased such that 75 percent RPM at full throttle is attained at the required end point, with good consistency. As discussed in Section 3.2, vehicles which reach 100 percent RPM near the end of the end-zone in the SAE J331a test exhibit near equal SAE J331a and F-76 levels. The Rokon 340RT fits this pattern, reinforcing the appropriateness of the above testing techniques.

The Husqvarna 360 Automatic incorporates four centrifugal clutches, with Sprague roller clutches which permit the lower geared centrifugal clutches to freewheel when the higher geared clutches engage. The SAE J331a test cannot be run, because 100 percent RPM is reached well before the start of the end-zone, and no rational criteria exists for regulating the throttle other than wide open. No technique has been developed which would achieve full throttle at 75 percent RPM at the prescribed point in relation to the microphone. Further analysis and testing will be required to develop a meaningful and repeatable test technique for this type of vehicle.

Based on the F-77 testing of two motorcycles with displacements less than 100 cc and six mopeds, no problems occurred with vehicles with automatic transmissions.

(2) Tachometers

A major problem encountered throughout EPA's test program was in obtaining engine RPM readings on motorcycles not equipped with tachometers. Portable tachometers used in the program included the Sanwa Model MT-03, the Rite Autotronics model 4036, and the Dynall Mode TAC 20. In most cases, one of these three tachometers could be made to function properly on the test vehicle, but none of these tachometers would work on all motorcycles. In some cases the testing of a motorcycle was abandoned because of inability to obtain proper functioning of the tachometer.

A vehicle manufacturer should have no difficulty in arriving at a suitable tachometer or other means of determining RPM for his particular line of vehicles; the problem exists primarily for the EPA and for after-market manufacturers, where universal application over many makes and models would be necessary. Fortunately, however, the steady-state accuracy of the tachometer (either the vehicle tachometer or a portable tachometer) can be readily verified simply by matching the engine firing frequency (as picked up by a wire placed in proximity to a spark plug lead) with a signal from a calibrated oscillator and matching the two signals on an oscilloscope.

A second factor to be considered in the use of tachometers for moving vehicle acceleration tests is tachometer lag, and the ability of the rider to close the throttle at the correct RPM. This effect was evaluated in a previous study[6], where results obtained using the vehicle tachometer were compared with results obtained using an electronic tachometer incorporating a "max. hold" mode (Emission Control Instruments, Precision Tachometer). In that study, when the rider performed SAE J47 tests on ten motorcycles using the vehicle tach for reference, the true RPM recorded by the electronic tach ranged from 1132 RPM high, to 356 RPM low, as compared to the intended RPM. When the SAE J47 tests were repeated with the closing RPM at the proper value established by the electronic tach, measured levels ranged from zero to 2 dB lower.

Test methodologies such as the SAE J331a and the F-76 (as opposed to the ISO/R-362 type) are subject to both the problems of tachometer functional compatibility and lag, unless other methods are established to measure engine speed. The dynamometer method is free of these problems, since the tachometer can be incorporated into the dynamometer, and measuring conditions are steady-state.

3.3 Stationary Vehicle Test Procedures

F-50 (Stationary vehicle test)

The F-50 procedure is patterned after the ISO proposed draft, "Method of Control of Noise Emitted by Stationary Motor Vehicles," July 1974. The test consists of running the engine up to 50 percent RPM, unloaded, and measuring noise at a distance of 0.5 m from the exhaust outlet, on a line displaced 45° from the exhaust axis. The complete text of this procedure and the ISO draft are in Appendix A.

Critique:

The F-50 levels, presented in Section 4, are relatively independent of displacement (Figure 4-7 and 4-8) and have been correlated with SAE J331a and F-76 levels in Figure 3-6 thru 3-9. The correlation is not sufficiently good as to permit the moving vehicle acceleration noise for a particular vehicle to be predicted from the stationary level. Major reasons for this

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[6] See page 3-40.

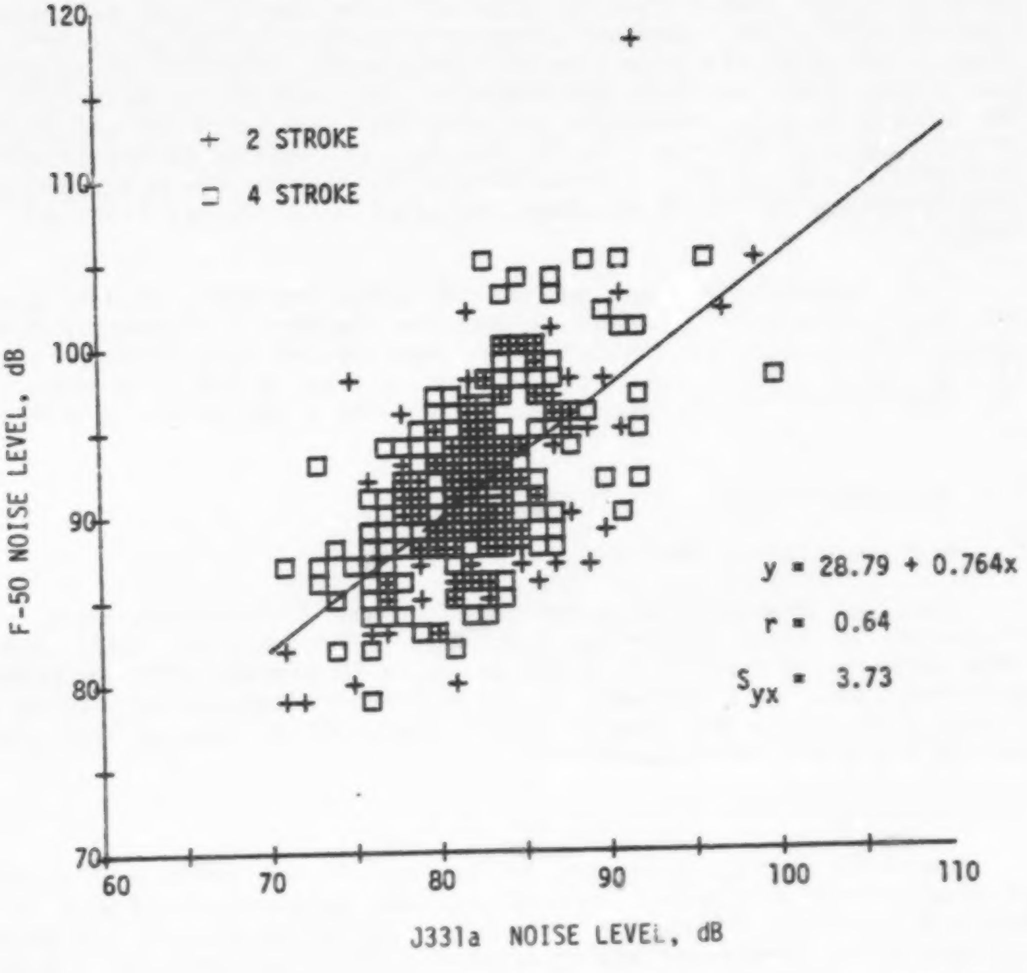


FIGURE 3-6 CORRELATION BETWEEN F-50 and J-331a TESTS, 1969-1976 MODEL STREET AND COMBINATION STREET/OFF-ROAD MOTORCYCLES

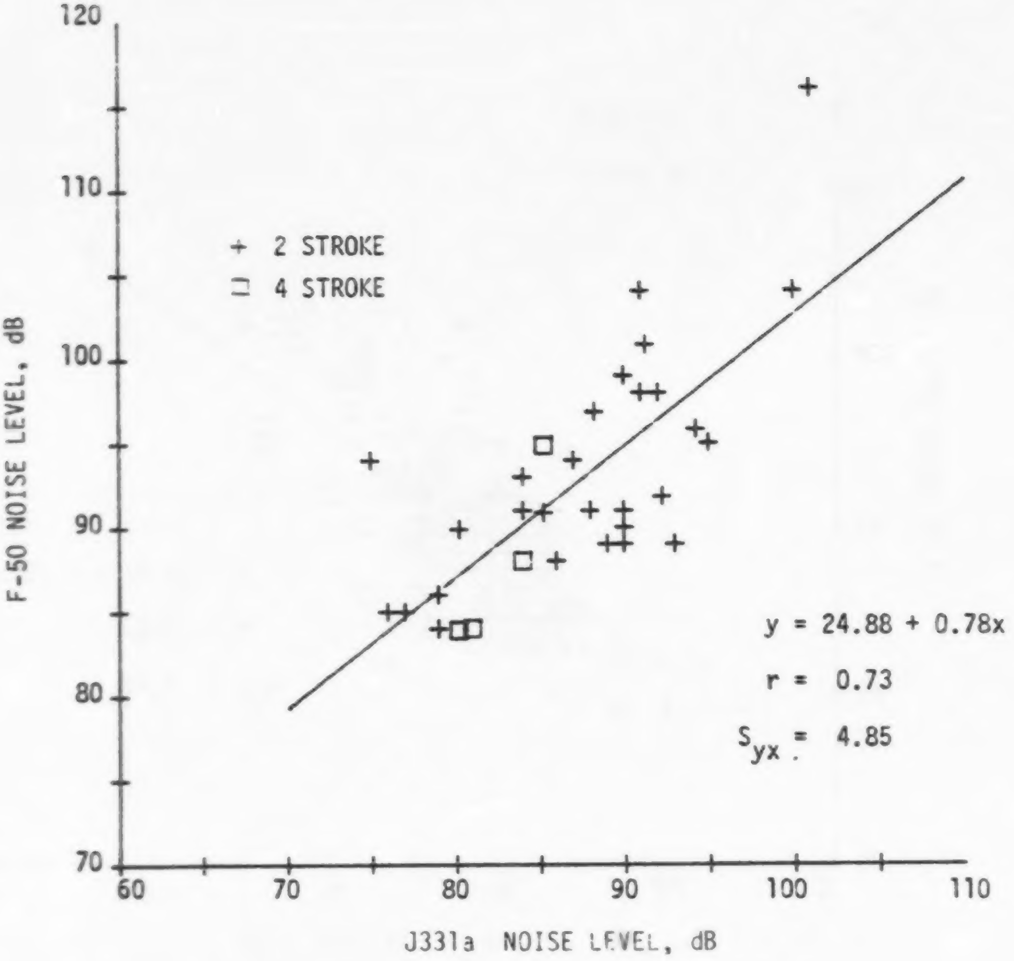


FIGURE 3-7 CORRELATION BETWEEN F-50 and J-331a TESTS, 1969-1976 MODEL OFF-ROAD (ONLY) MOTORCYCLES

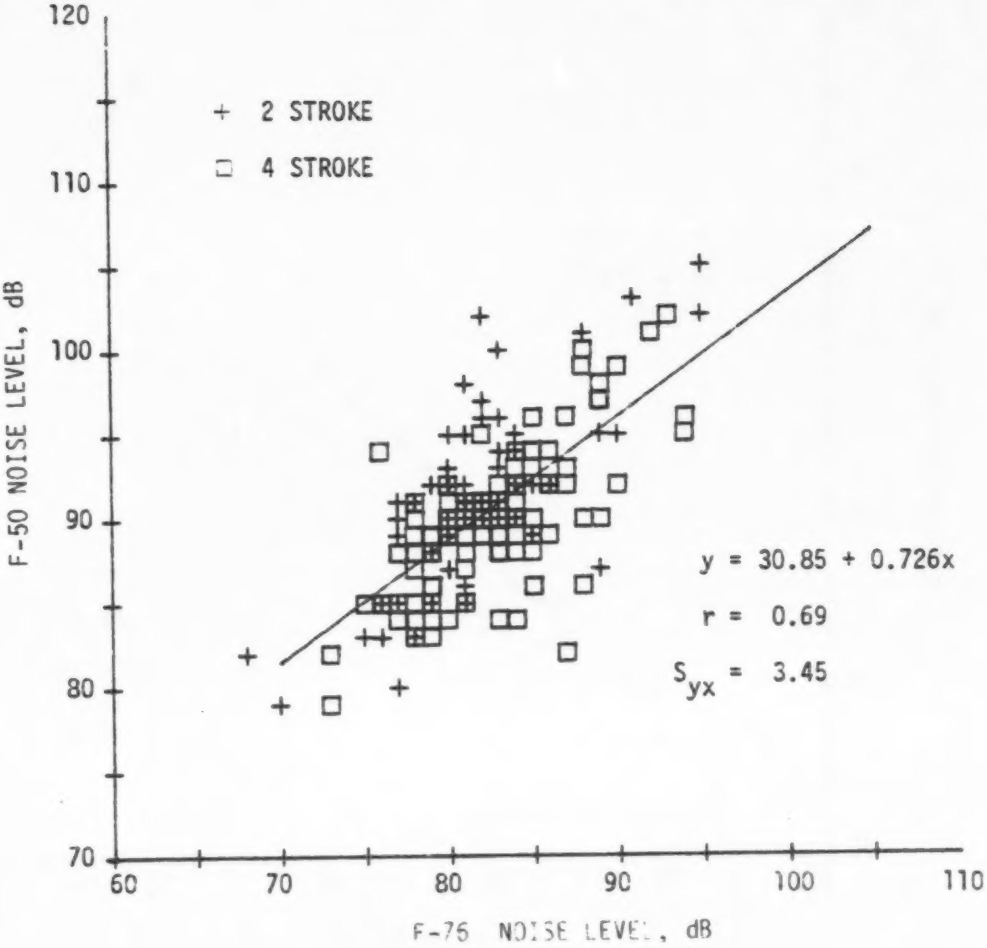


FIGURE 3-8 CORRELATION BETWEEN F-50 AND F-76 TESTS, 1969-1976 MODEL STREET AND COMBINATION STREET/OFF-ROAD MOTORCYCLES

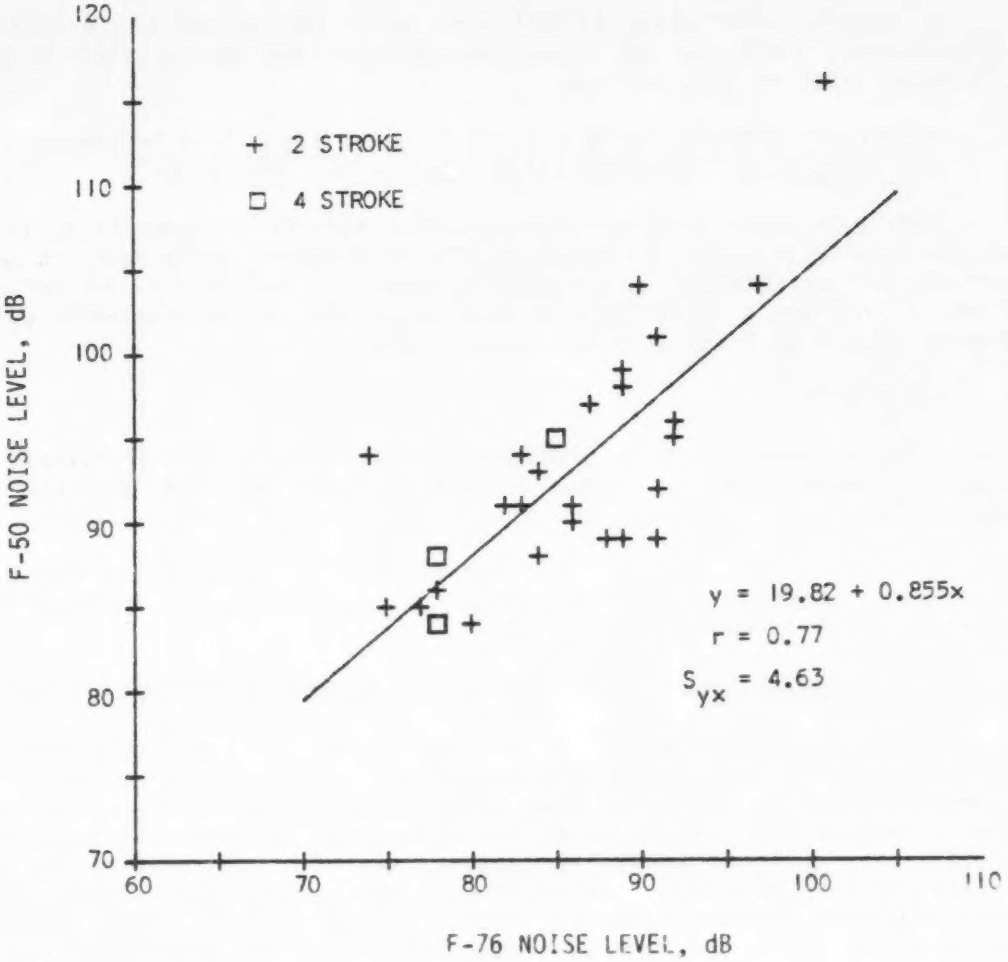


FIGURE 3-9 CORRELATION BETWEEN F-50 AND F-76 TESTS, 1967 - 1976 MODEL OFF-ROAD (ONLY) MOTORCYCLES

are that the engine is not under load, and thus exhaust noise is not representative of the acceleration conditions, and because the throttle is only partially open, intake noise is not fully developed.

The test is nevertheless of potential value. Figures 3-10 and 3-11 show that in general an exhaust system change which produces higher moving vehicle noise levels also results in higher levels in the stationary test. The correspondence in this respect is sufficiently good that the method could be used for on-the-road enforcement against exhaust system tampering. The figures show that the method would be quite effective against flagrant violators, providing the OEM (original equipment manufacturer) noise level was known and labeled on the machine.

A further alternative to the F-50 test, for use by the exhaust system manufacturer, could be the dyno-simulation of the moving vehicle test, as discussed later in this section.

Motorcycle Industry Council (MIC) Proposed Field Test Procedure for Noise Levels of Competition Motorcycles, Rev. 1-30-76

This procedure, the full text of which appears in Appendix A, is similar to the F-50 procedure, differing mainly in features which make it more convenient for application in competitive events. Test RPM is 50 percent redline, alternatively 60 percent maximum rated RPM, or alternatively calculated from a formula as a function of stroke dimension.

Critique:

(a) The features of this procedure (which enhance its usefulness in the intended application) introduce a lack of precision not desirable in EPA applications.

(b) The procedure provides for the testing of motorcycles not having a "neutral" transmission position; this is accomplished by raising the rear wheel or removing the chain.

F-76 Dyno-Simulation (simulated moving vehicle acceleration test)

A cursory investigation of the feasibility of simulating moving vehicle acceleration tests on a dynamometer was conducted, using one motorcycle (Honda CB 750) and a Pabatco Dyno (made by Weda Instruments). This dynamometer is one of the lowest priced portable units commercially available, not specifically designed for noise testing, and not incorporating any quieting provisions (Figure 3-12). The motorcycle was successively fitted with seventeen different exhaust systems, which resulted in F-76 levels ranging from 82 to 98 dB. For the dyno-simulated F-76 test, the dynamometer was set up at the test site at the F-76 test track end point, with the microphone positioned as it would be for the actual F-76 test moving vehicle test. Noise level as measured at 75 percent RPM at full throttle was established, a procedure taking about 15 seconds. Figure 3-13 presents the correlation of results from this test and the actual F-76 moving vehicle test. Readings were taken only on the left side of the motorcycle, even though some of the exhaust systems were on the right side only; this because the dynamometer configuration precluded taking readings on the right side.

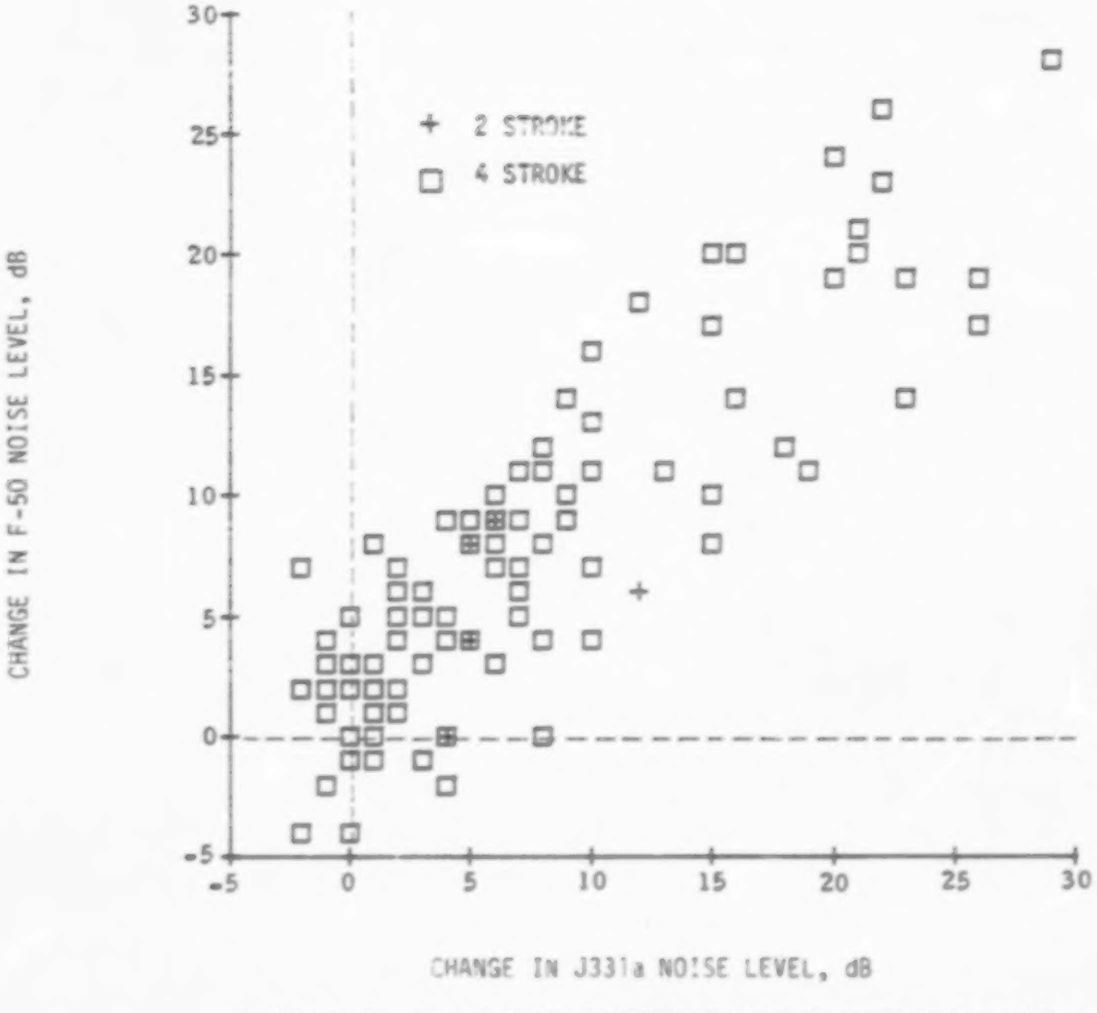


FIGURE 3-10 CORRELATION BETWEEN CHANGE IN F-50 NOISE LEVEL COMPARED TO CHANGE IN J331a NOISE LEVEL, AFTERMARKET AND MODIFIED CONFIGURATIONS REFERRED TO ORIGINAL MANUFACTURE

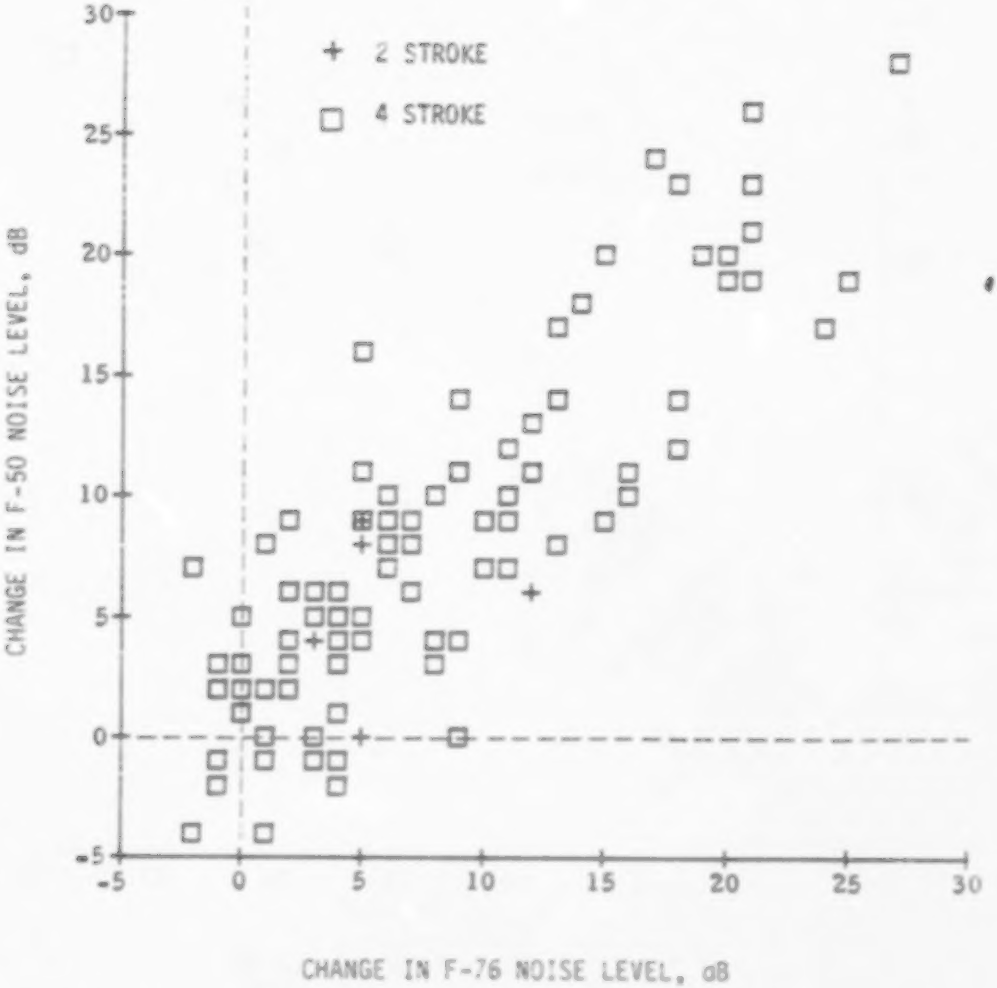


FIGURE 3-11 CORRELATION BETWEEN CHANGE IN F-50 NOISE LEVEL COMPARED TO CHANGE IN F-76 NOISE LEVEL, AFTERMARKET AND MODIFIED CONFIGURATIONS REFERRED TO ORIGINAL MANUFACTURE

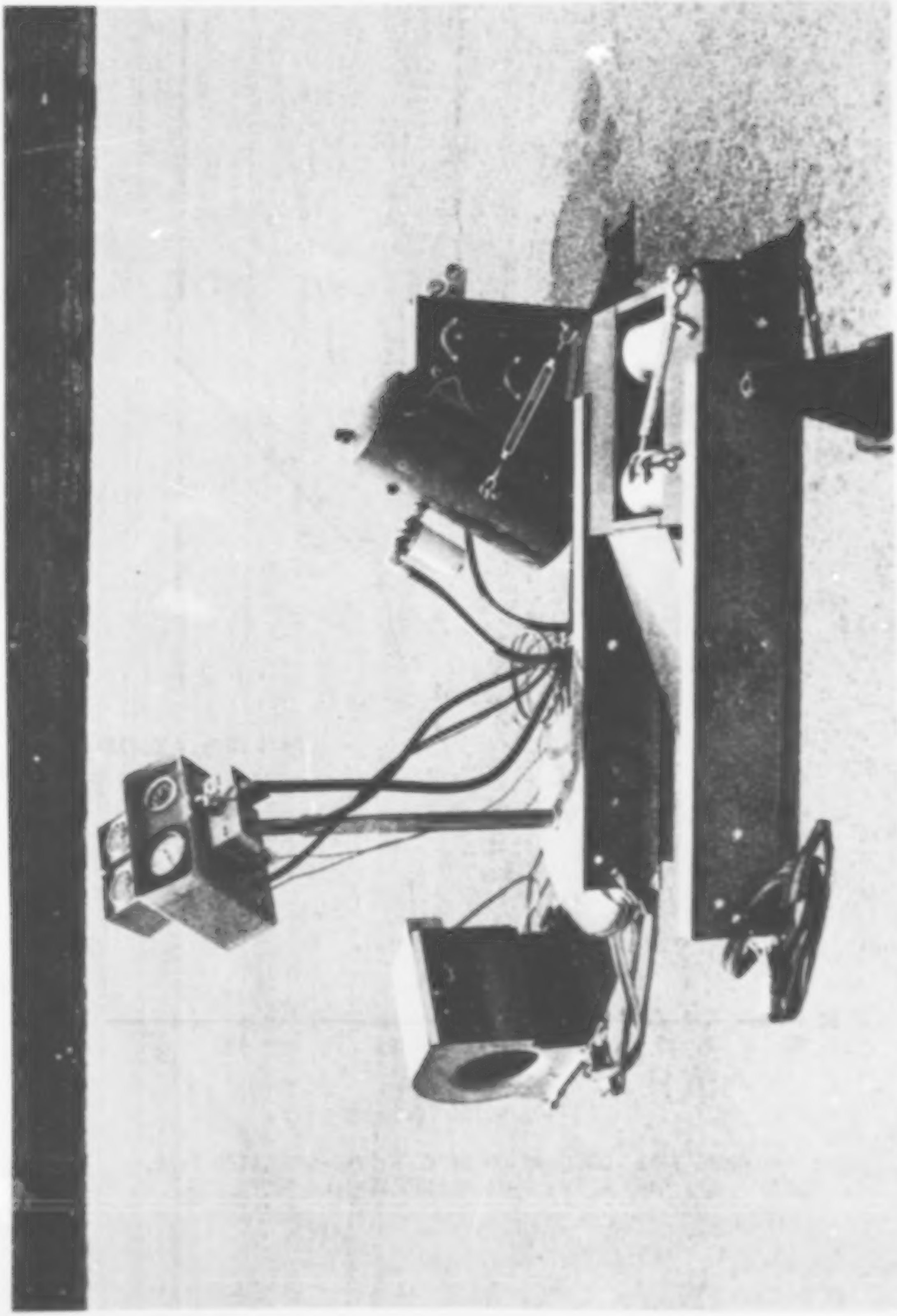


FIGURE 3-12 PABATCO DYNAMOMETER

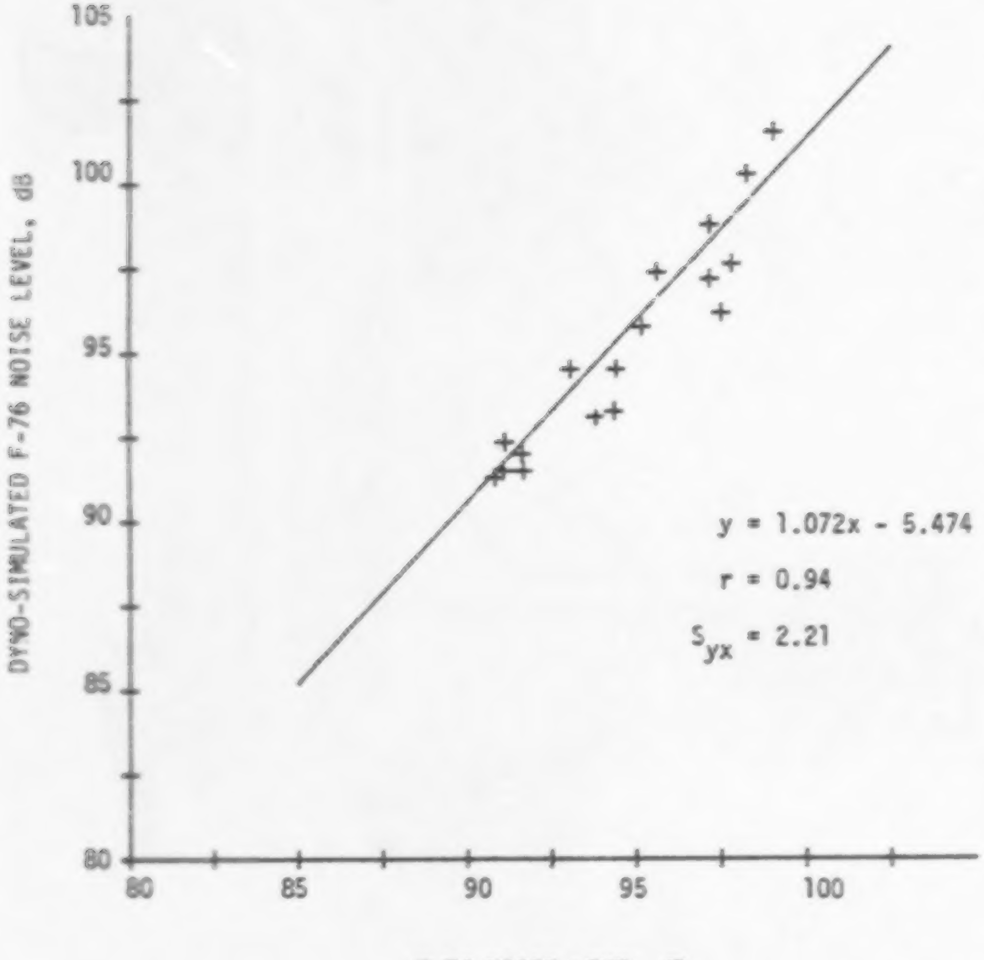


FIGURE 3-13 CORRELATION BETWEEN DYNO-SYMULATED F-76, AND ACTUAL F-76 MOVING VEHICLE TEST

Potential advantages of the dynamometer test method include:

- lower testing cost
- removal of schedule constraints due to weather
- greatly reduced area requirements
- no transportation of vehicles to and from test site
- greater accuracy by testing at a steady state condition rather than at a changing condition
- no problems with tachometer functioning, accuracy, or lag
- removal of testing variables such as throttle closure, distance determination
- removal of wind, weather, micro-meteorological variables
- minimization of site variables

As discussed in Section 3.2, dyno-simulation of the SAE J331a or ISO/R-362 test procedures is not feasible.

3.4 Measurement Distance Substitution

All of the noise emission data presented in this report were measured at a 50-foot distance (except the F-50 data, which were measured at 0.5 m), as delineated in the respective procedures. An investigation was made, however, to determine feasibility of taking measurements at 25 feet, and correcting the measured values to a 50-foot equivalent. Results of this investigation are shown in Table 3-3 and Figures 3-14 and 3-15; it is evident that no such conversion is possible in the case of an acceleration test (as opposed to a constant speed test).

The reason for the lack of correspondence between the 50-foot and 25-foot measurements was not investigated; it may be that the vehicle noise exhibits a changing polar pattern as the vehicle accelerates, such that a lobe changes in magnitude as it passes from one microphone to the other, or it may relate to a changing interference relationship (discussed in section 4.2) resulting from spectral changes as the vehicle moves past the microphones with changing RPM.

TABLE 3-3 RELATIONSHIP BETWEEN 25 FT. AND 50 FT. NOISE LEVEL MEASUREMENTS

BIKE NO.	DISPL. CC	ENGINE TYPE *	DIFFERENCE BETWEEN 25 FT AND 50 FT NOISE LEVEL READINGS, dB				
			J331a	F76	F77	R_{60}	55 MPH
101	356	4 S	5.6	6.2			
102	72	4 S	3.1	4.3			
103	123	2 S	5.0				
104	999	4 S	5.8	5.4			
105	736	4 S	7.6				
109	248	4 S	5.0				
110	124	4 S	1.6	1.9			
111	171	2 S		4.1			
112	99	4 S	2.1				
113	248	4 S	2.8				
114	99	2 S	3.5	4.1			
115	99	2 S	4.6	4.8			
117	99	2 S	3.1	3.8			
118	174	2 S		5.0			
119	400	2 S	4.0	6.0			
120	746	4 S	3.5				
140	828	4 S	4.5	5.4			
141	49	2 S			5.0		
142	744	4 S	6.3	7.2			
143	246	2 S	6.5	6.9			
145	981	4 S	5.1	5.3			
146	246	2 S	3.6	5.9			
146	246	2 S		5.3			
151	949	4 S	7.3	7.3			6.6
151	949	4 S	6.7				
152	336	2 S	5.5				4.7
155	98	2 S	4.6	4.1			
155	98	2 S	4.3				
156	72	2 S	3.5	4.6	5.3		
157	49	2 S			6.5		
158	898	4 S	5.8	8.1			6.6
159	750	4 S	5.4	6.1			7.0
160	736	4 S	4.4				
160	736	4 S	5.2				
160	736	4 S	6.9				
161	247	2 S	4.8	4.7			
161	247	2 S	5.9				
162	124	2 S	6.8	5.8			6.0
163	903	4 S	7.1	6.6		6.6	5.2

* 2S denotes 2 stroke
4S denotes 4 stroke

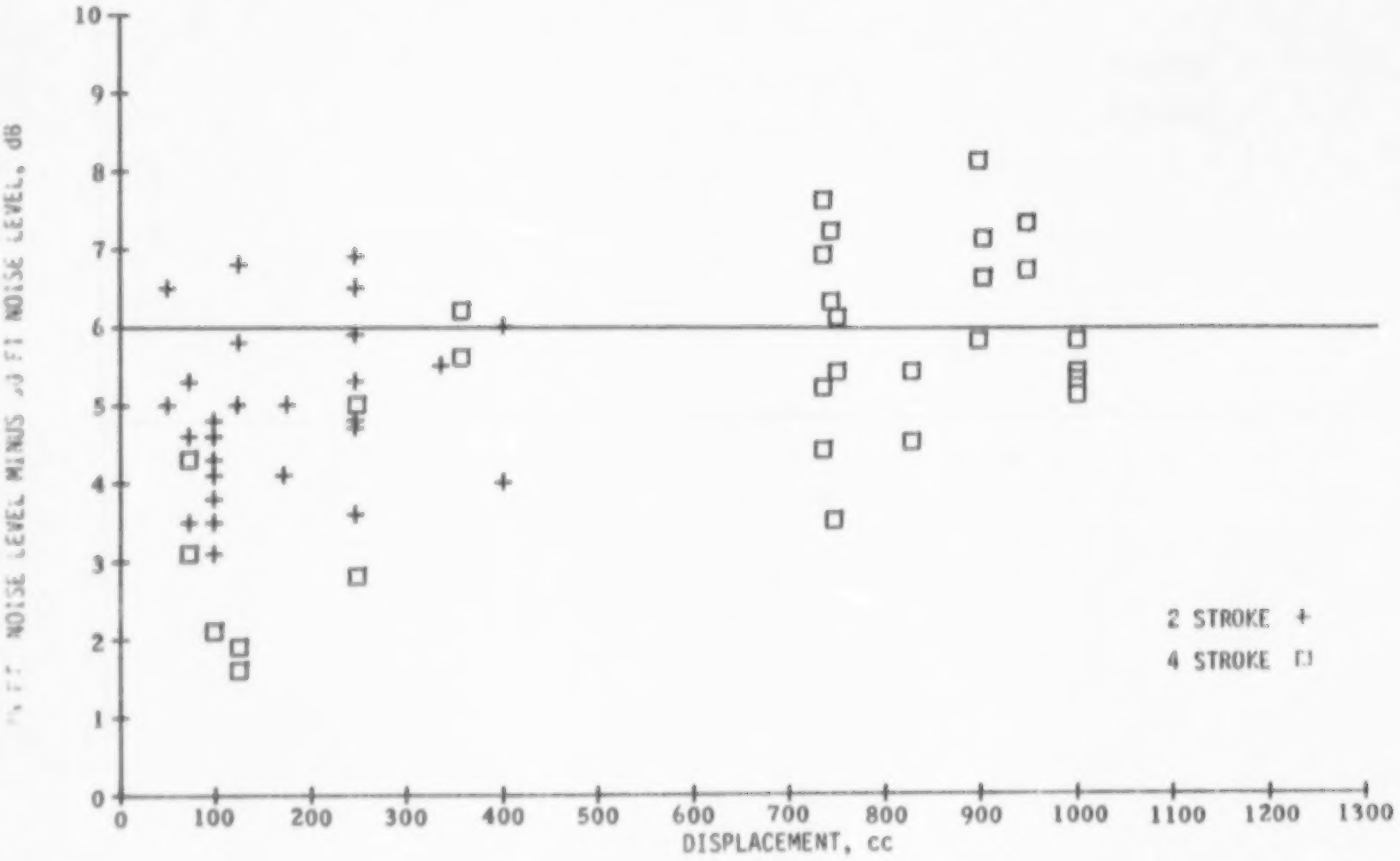


FIGURE 3-14 DIFFERENCE BETWEEN 50 FT. AND 25 FT. MEASURED NOISE LEVELS DURING ACCELERATION (J331a AND F-76) TESTS

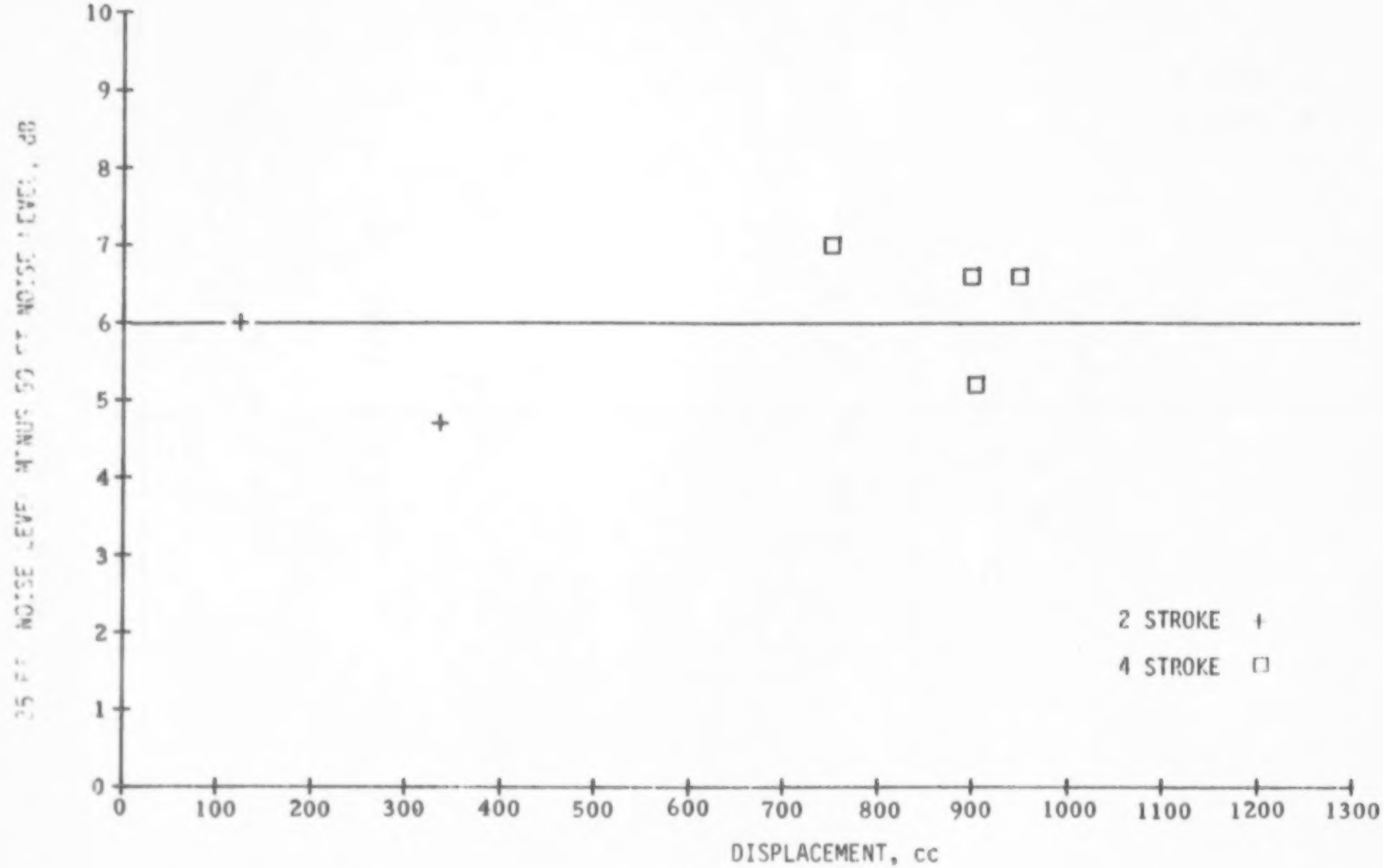


FIGURE 3-15 DIFFERENCE BETWEEN 50 FT. AND 25 FT. MEASURED NOISE LEVELS DURING CONSTANT SPEED (35 MPH AND 55 MPH) TESTS

REFERENCES

1. Motorcycle Noise Studies, report published by the Japan Automobile Manufacturers Association, Inc., Motorcycle Noise Control Committee, July, 1975.

2. Hornett, H. and Williamson, I. M., Evaluation of Stationary and Moving Motorcycle Noise Test Methods for Use in Proposed Regulations, McDonnell Douglas Astronautics Company report prepared for the Motorcycle Industry Council, Inc.

SECTION 4

NOISE LEVEL DATA BASE

SECTION 4

NOISE LEVEL DATA BASE

4.1 Content and Format of the Data Base

The basic motorcycle noise level data base used for this regulation is presented in Appendix C. Noise data for the following are included:

(a) 159 new 1976 model year motorcycles (manufactured in 1975 and 1976);

(b) 60 motorcycles (manufactured in 1974) in stock configuration;

(c) 257 in-service motorcycles in stock configuration, manufactured 1969-1973 (includes the data developed in the MIC motorcycle testing program);

(d) 43 in-service modified motorcycles, manufactured 1969-1976;

(e) 107 motorcycles with new aftermarket exhaust systems.

Motorcycles in group "a" above provide the best noise level baseline for assessing cost and economic impact of adoption of standards more stringent than 83 dB (for street motorcycles) which is the standard currently in effect in some states (e.g., California). Street motorcycles manufactured prior to 1975 have been subject to less stringent standards and are therefore not representative of current technology applications and cost.

Off-road motorcycles in groups "a", "b", and "c" can be included in the baseline data for the off-road category, since regulation of noise emissions from those vehicles has been very limited in most states.

Motorcycles in group "a" through "d" provide a baseline for assessing environmental improvement that can result from regulation of the new vehicle, the aftermarket product, and user modifications.

Motorcycle aftermarket data, group "e", show the degree to which currently offered-for-sale aftermarket exhaust systems affect new vehicle noise emissions.

The total sample of vehicles, groups "a" through "e" above, were employed in the development and/or evaluation of test methodologies (Section 3) in the course of acquiring the data base.

The following makes and models are represented:

Benelli 750 SEI
BMW R90/6
BMW R90S
BMW R60/6
Bultaco 250 Alpina
Bultaco Frontera
Bultaco 350 Sperpa T
Bulotaco Matador MK9
Bulotaco 250 Pursang
Can Am 125 TNT
Can Am 250 TNT
Can AM 250 MX1
Carabela 125 Marquesa MX
Carabela 250 Centauro
Ducati DM750S
Garelli Moped
Harley FXE-1200
Harley FLH-1200
Harley SS125
Harley SS175
Harley SS250
Harley SX 125
Harley SX 175
Harley SX 250
Harley XLH1000
Hodaka Road Toad
Hodaka 250
Honda CB 400F
Honda CB 500T
Honda CB 750A
Honda CB125S
Honda CB 1255
Honda CB200T
Honda CB350F
Honda CB 360T
Honda CB 450
Honda CB 550
Honda CB 550F
Honda CB 550T
Honda CB 750
Honda CB 750F
Honda CJ360T
Honda CL360
Honda CL450
Honda CR125M
Honda CT70
Honda GL1000
Honda MR50
Honda MR175
Honda MR125
Honda TL250
Honda XL70
Honda XL70K2
Honda XL100
Honda XL125
Honda XL175
Honda XL250
Honda XL350
Honda XR-75
Honda Z50A
Honda All terrain
Honda CT90
Honda NC50
Husqvarna 360 Automatic
Husqvarna 360 WRX
Indian MT175
Kawasaki 900Z1
Kawasaki KD80
Kawasaki KE125
Kawasaki KE175
Kawasaki KH 100
Kawasaki KH 250
Kawasaki KH 400
Kawasaki KM 100A
Kawasaki KT 250
Kawasaki KV 75
Kawasaki KV 100
Kawasaki KZ 400
Kawasaki KZ 400D
Kawasaki KZ 400S
Kawasaki KZ 750
Kawasaki KZ 900
Kawasaki KZ 900LTD
Kreidler MP3
Laverda 750SF
Larerda 1000Three
Montesa 250 Enduro
Montesa Cota 123
Montesa Cota 247
Montesa Cota 348
Motobecane Mobylette Moped
Moto Guzzi 1000 Convert
Moto Morini 3 1/2
Moto Guzzi 850-T
Norton 860 Commando
NVT ERB Moped
Ossa Desert Phantom 250
Ossa 250 Pioneer
Ossa 250 Plonker
Peugeot 103 LVS V3
Rokon RT -340 11
Suzuki GT185
Suzuki GT380
Suzuki GT500
Suzuki GT550
Suzuki GT750
Suzuki RE-5 Rotary
Suzuki RM125
Suzuki RV90
Suzuki TM75
Suzuki TS100
Suzuki TS185
Suzuki TS400A
Suzuki TS400S
Velosolex 4600 Moped
Vespa Ciao Moped
Yamaha Chappy
Yamaha DT100C
Yamaha DT175
Yamaha DT175C
Yamaha DT250
Yamaha DT250C
Yamaha DT400C
Yamaha DT650C
Yamaha MX125
Yamaha RD125B
Yamaha RD200B
Yamaha RD200C
Yamaha RD250
Yamaha RD350
Yamaha RD400C
Yamaha RS100B
Yamaha TX750
Yamaha TY80
Yamaha XS360C
Yamaha XS650B
Yamaha XS650C
Yamaha XT500C
Yamaha XT500
Yamaha YZ125C

The vehicle population tested encompassed street, off-road, and combination use motorcycles; 50 to 1200 cc displacement; 2-stroke, 4-stroke and rotary engines; 1, 2, 3, 4, and 6 cylinders; manual gear shift, automatic clutch, hydraulic torque converter, and centrifugal torque converter transmissions; a few mopeds were also included.

Test methodologies employed in acquiring the data base include the SAE J331a, F-76, and R-60 acceleration tests; the F-77 full-speed/full-throttle test for under-100 cc bikes; the F-50 stationary vehicle test; and a dyno simulation of the F-76 test. These test procedures are described in Section 3 and detailed in Appendix A. Noise levels at 35 mph and 55 mph, constant speed pass-by, have also been obtained on a representative group of vehicles.

The noise level data base of new motorcycles manufactured 1975-1976 is presented primarily in terms of SAE J331a, F-76, and F-50 noise measurements. The data base is presented graphically in Figures 4-1 thru 4-10, and in tabular detail in Appendix C. Format of the graphical presentations is as follows:

(a) SAE J331a levels vs displacement -- Figures 4-1 and 4-2

(b) F-76 levels vs displacement -- Figures 4-3 and 4-4

(c) Transfer function F-76:SAE J331a, by displacement category and overall -- Figures 4-5 and 4-6

(d) F-50 levels vs displacement -- Figures 4-7 and 4-8

(e) 35 mph steady speed levels vs displacement -- Figure 4-9

(f) 55 mph steady speed levels vs displacement -- Figure 4-10

Tabular detail of noise emissions presented in Appendix C includes not only that for new 1975-1976 year of manufacture motorcycles, but also similar data for 1969- 1974 in-service motorcycles, motorcycles with modified exhaust systems, and data on aftermarket products. The tabular presentations include:

(a) Noise levels (SAE J331a, F-76, R-60, F-77, F-50, 35 mph, 55 mph) by displacement and use categories; new motorcycles, year of manufacture 1975 and 1976: Table C-4.

(b) Same data as Table C-4; by manufacturer: Table C-5.

(c) Noise levels (SAE J331a, F-76, F-77, F-50, 35 mph, 55 mph) by displacement and use categories; in-service motorcycles, year of manufacture 1969-1974, in stock configuration: Table C-6.

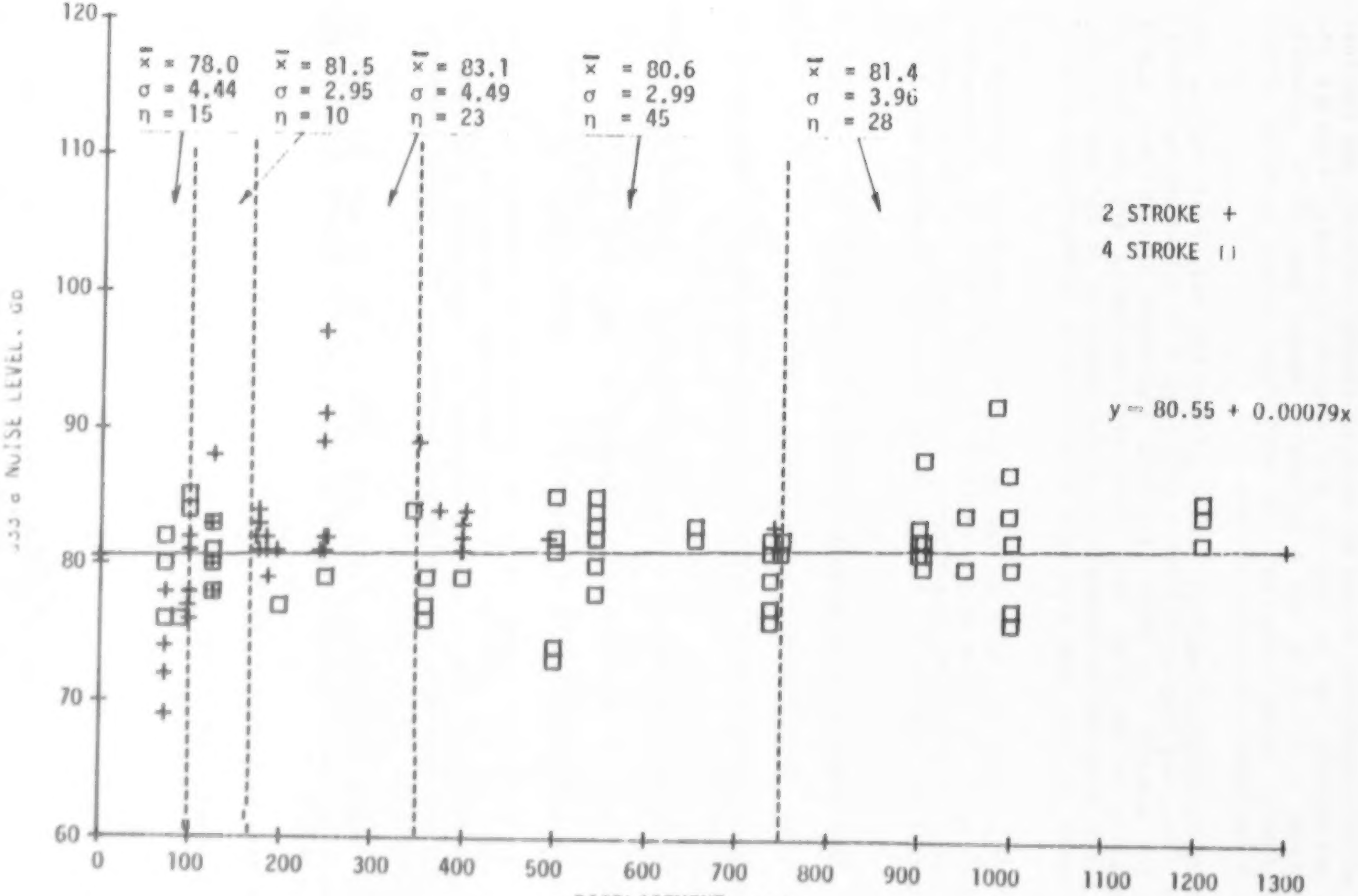


FIGURE 4-1 J331a NOISE LEVELS, STREET AND COMBINATION STREET / OFF-ROAD MOTORCYCLES MANUFACTURED 1975-1976

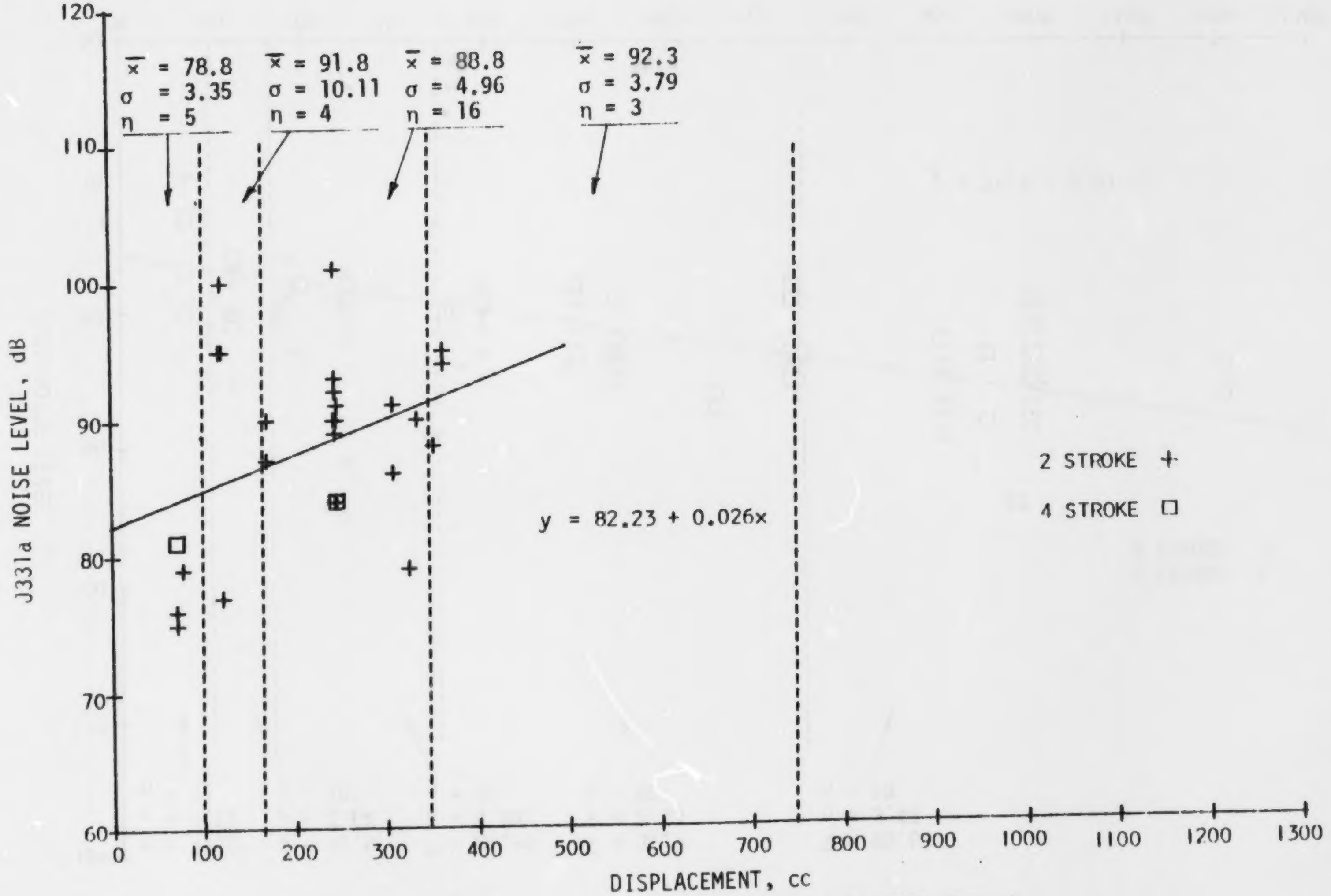


FIGURE 4-2 J331a NOISE LEVELS, OFF-ROAD (ONLY) MOTORCYCLES MANUFACTURED 1975-1976

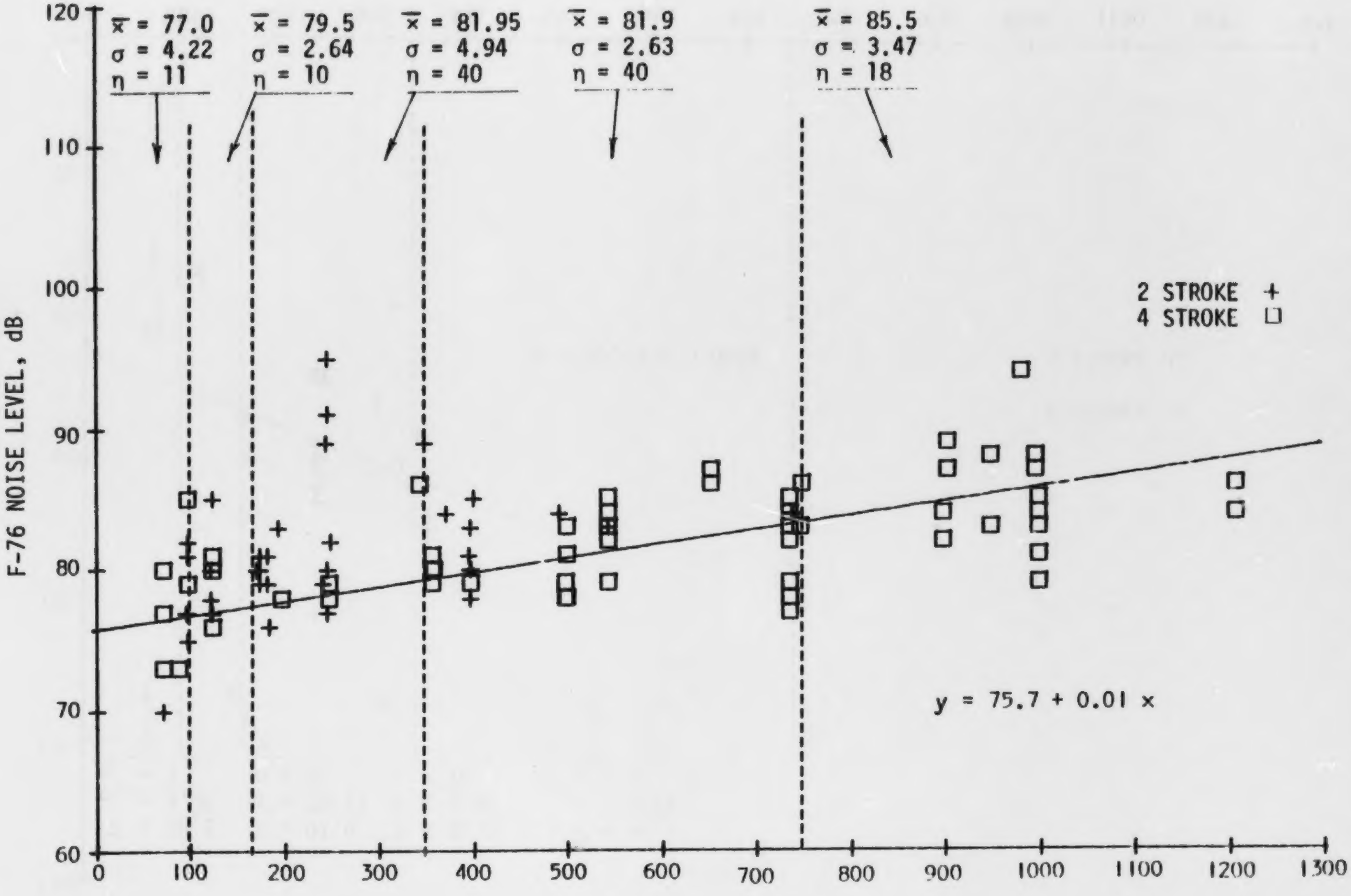


FIGURE 4-3 F-76 NOISE LEVELS, STREET AND COMBINATION STREET/OFF-ROAD MOTORCYCLES MANUFACTURED 1975-1976

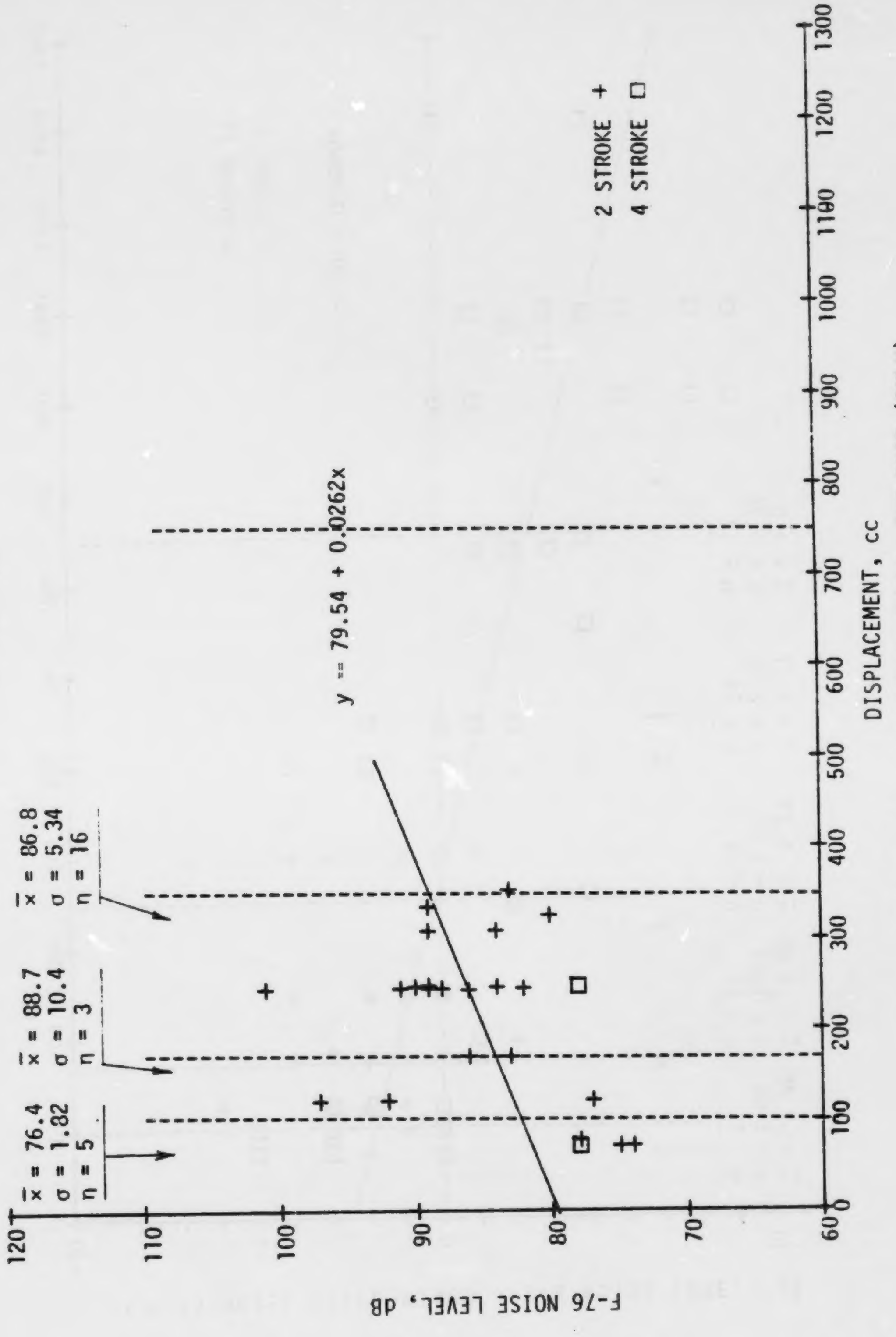


FIGURE 4-4 F-76 NOISE LEVELS, OFF-ROAD (ONLY) MOTORCYCLES MANUFACTURED 1975-1976

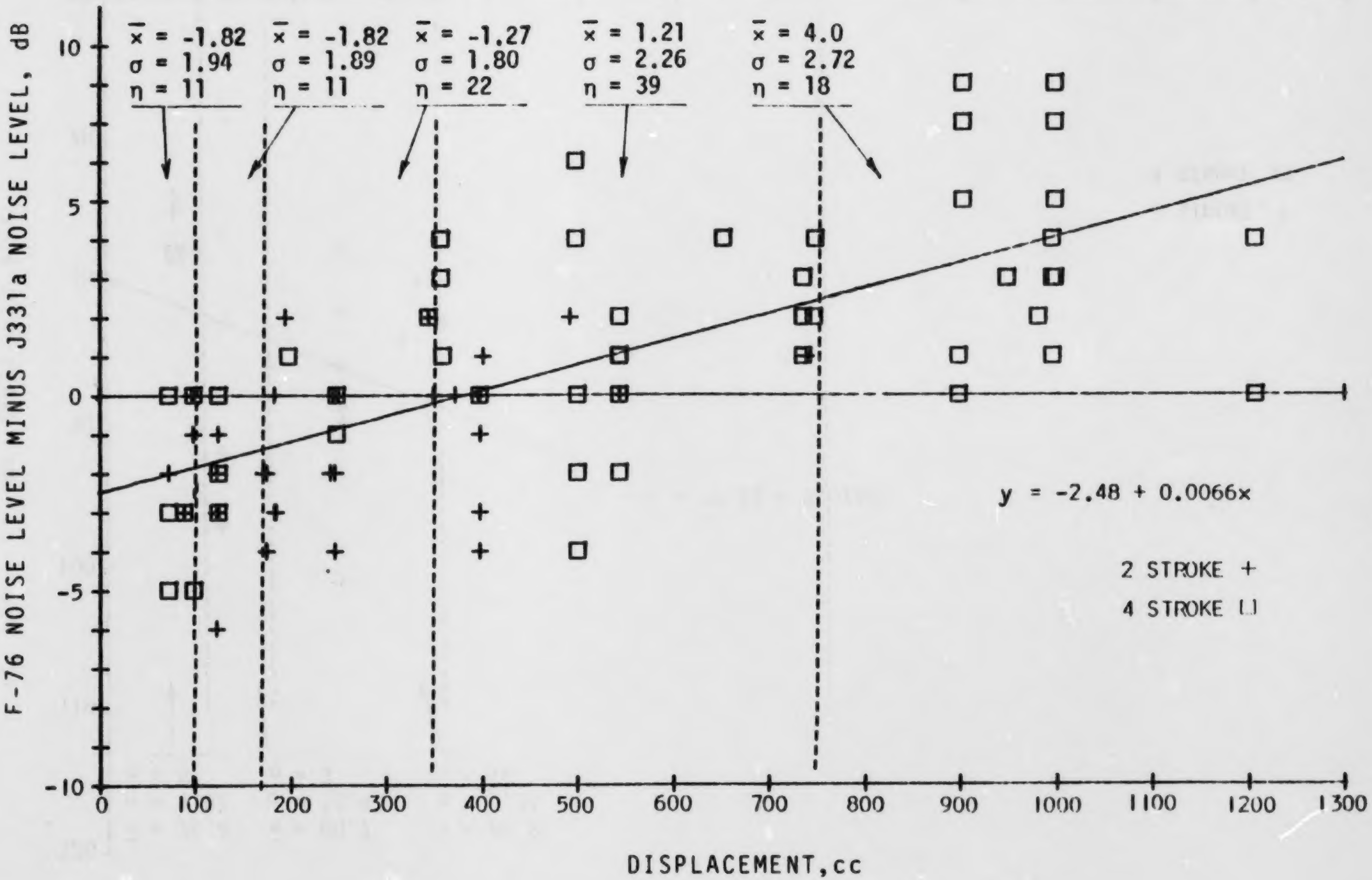


FIGURE 4-5 COMPARISON OF F-76 AND J331a NOISE LEVELS
STREET AND COMBINATION STREET/OFF-ROAD
MOTORCYCLES MANUFACTURED 1975-1976

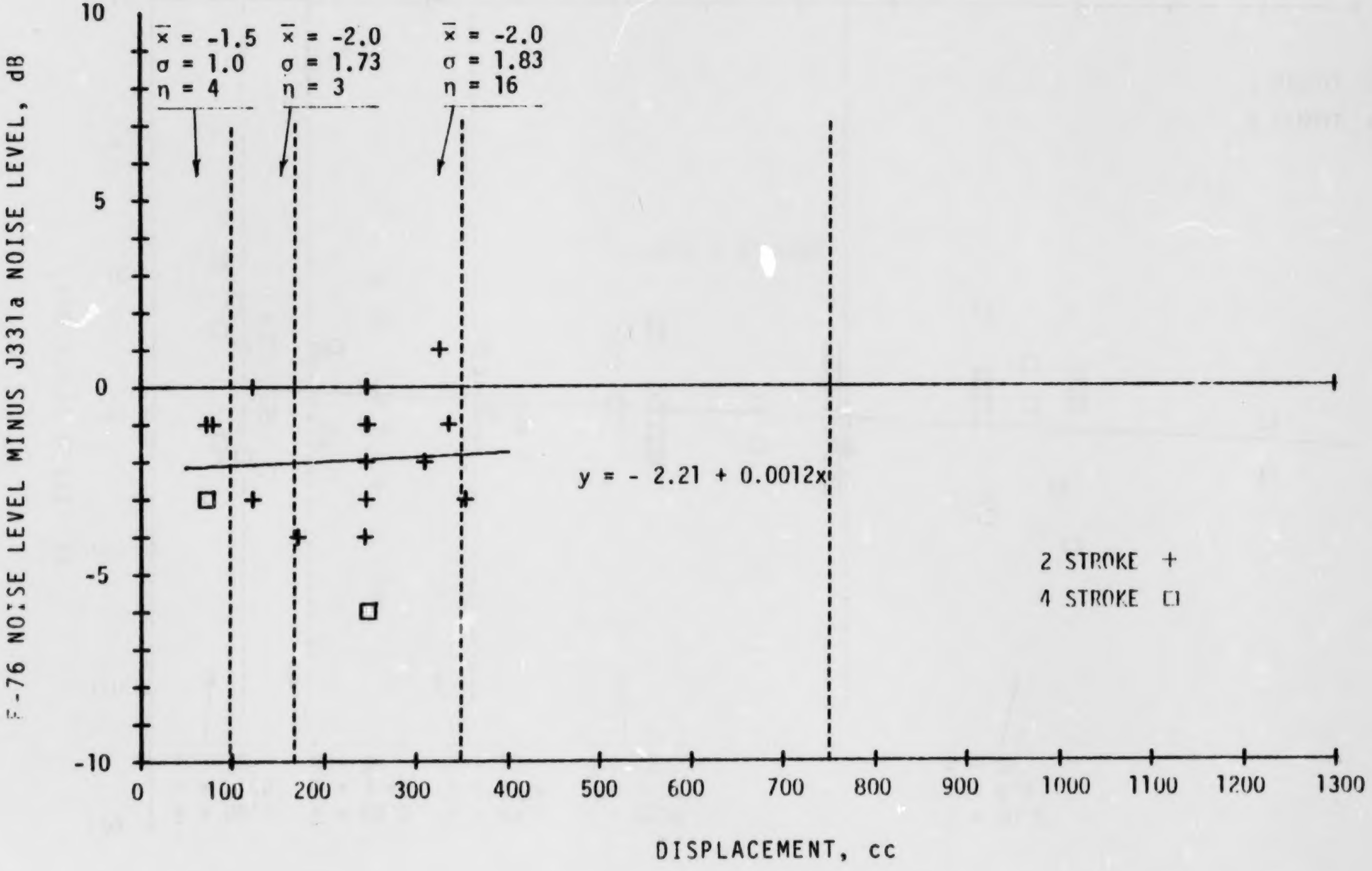


FIGURE 4-6 COMPARISON OF F-76 AND J331a NOISE LEVELS, OFF-ROAD (ONLY) MOTORCYCLES MANUFACTURED 1975-1976

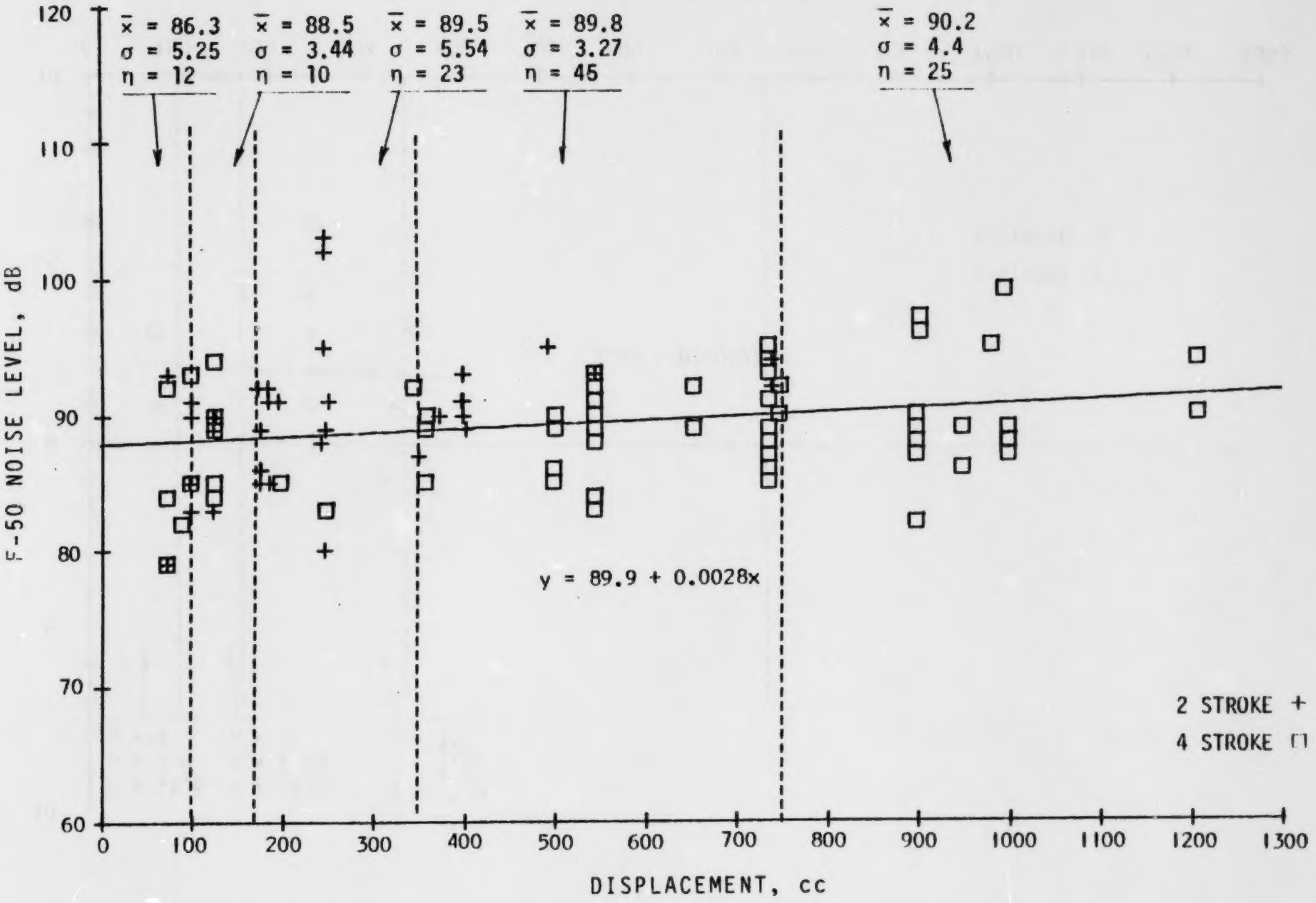


FIGURE 4-7 F-50 NOISE LEVELS, STREET AND COMBINATION STREET/OFF-ROAD MOTORCYCLES MANUFACTURED 1975-1976

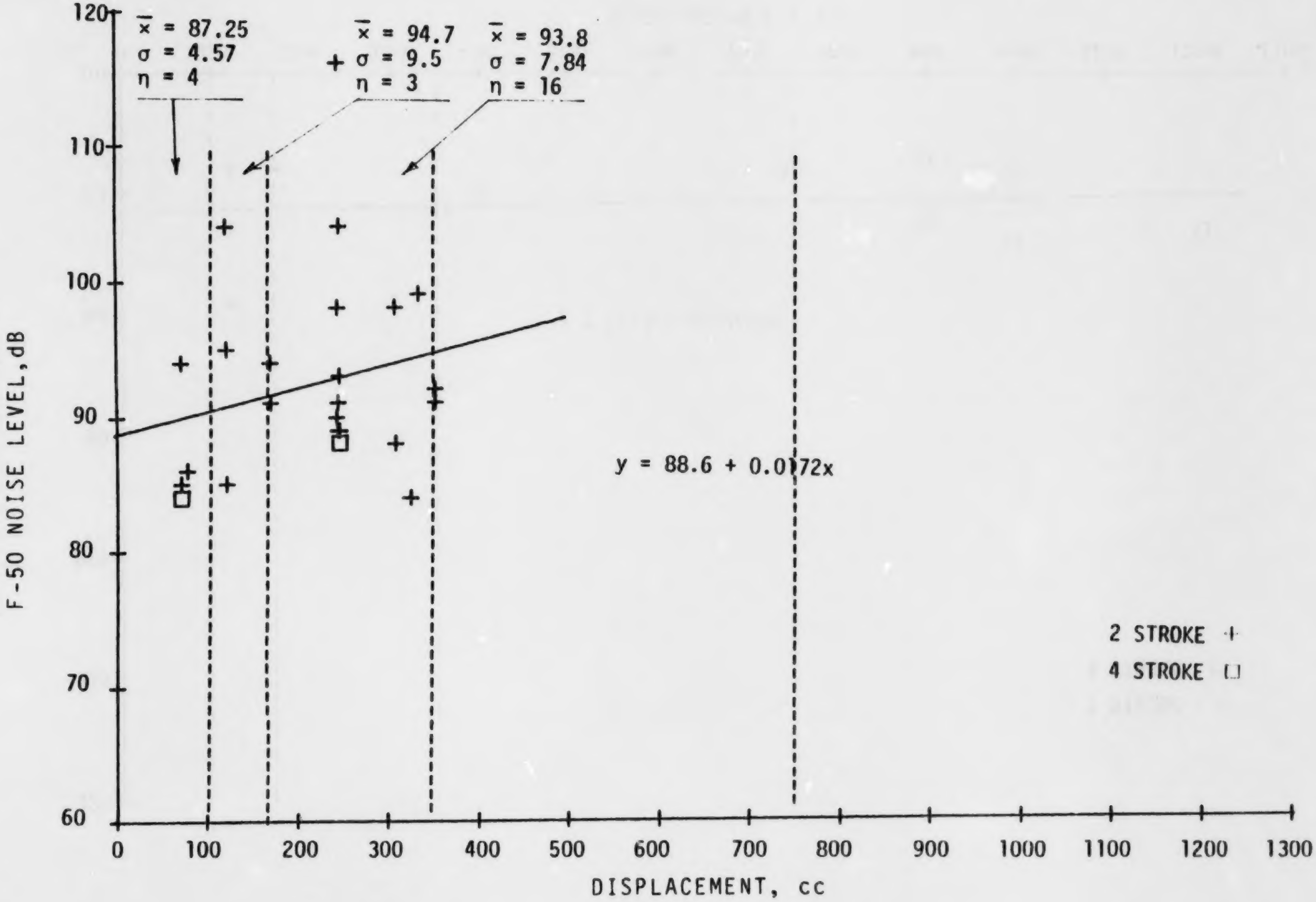


FIGURE 4-8 F-50 NOISE LEVELS, OFF-ROAD (ONLY
MOTORCYCLES MANUFACTURED 1975-1976

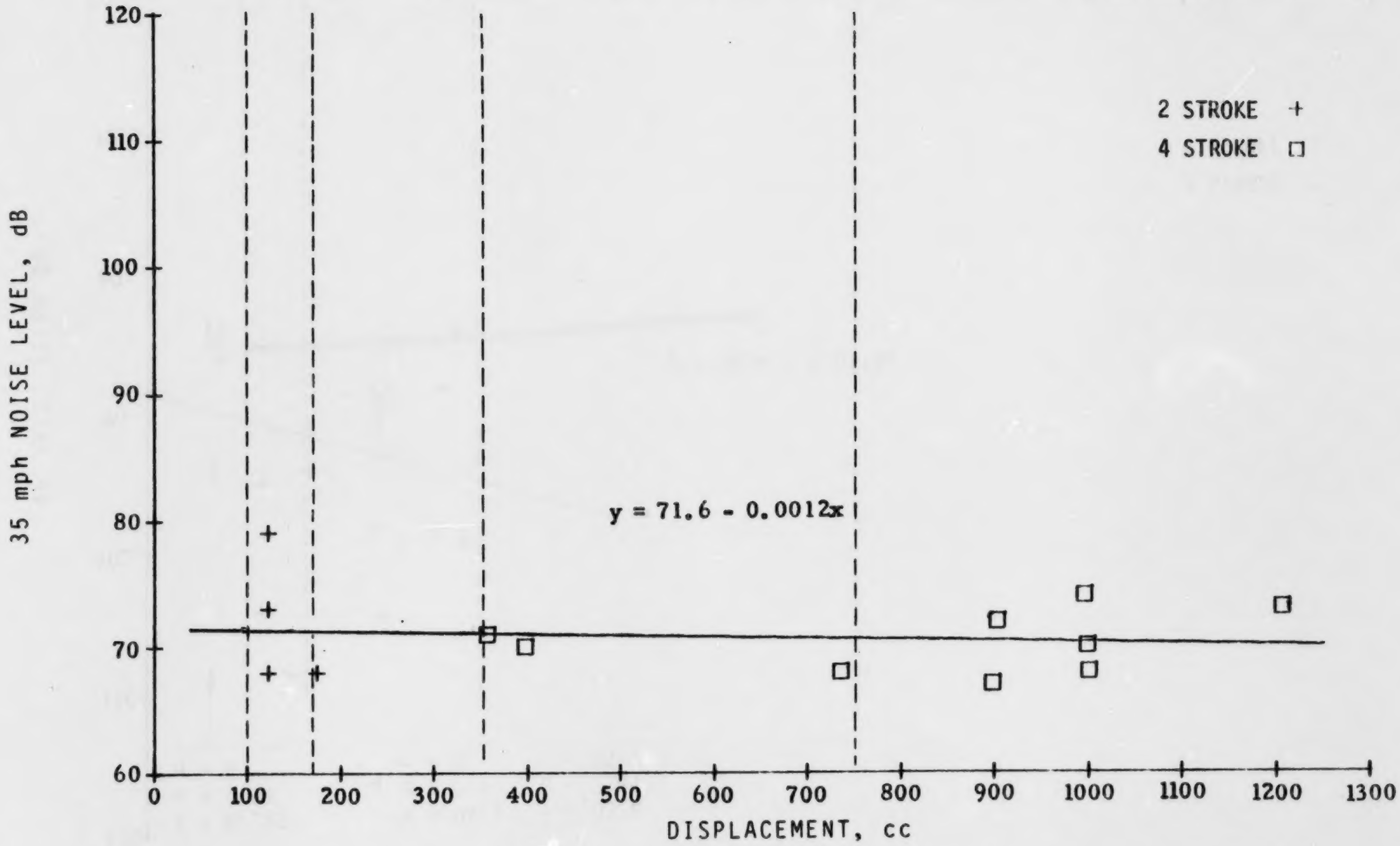


FIGURE 4-9 35 mph NOISE LEVELS, STREET AND COMBINATION STREET/OFF-ROAD MOTORCYCLES MANUFACTURED 1975-1976

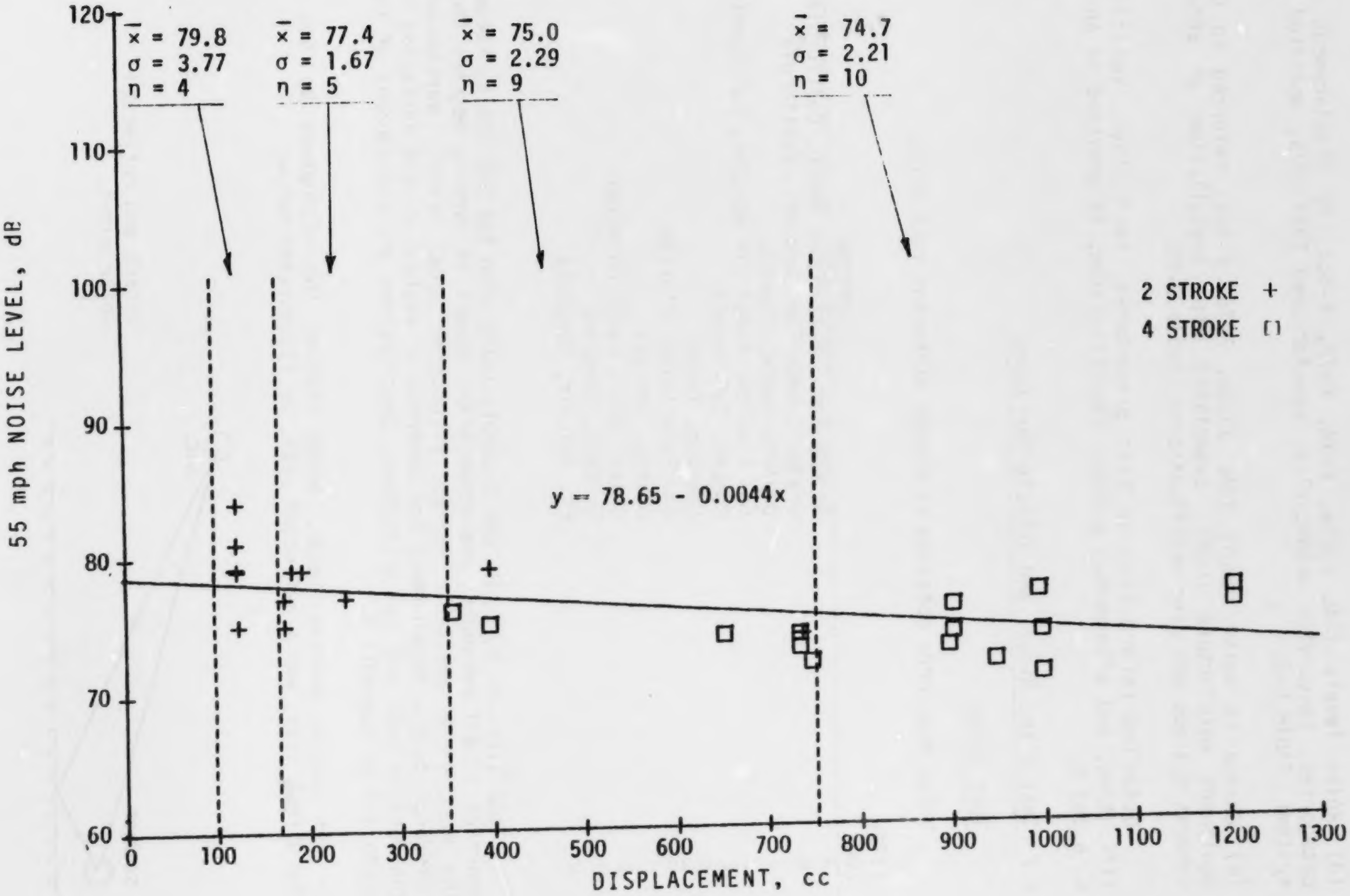


FIGURE 4-10 55 mph NOISE LEVELS, STREET AND COMBINATION STREET / OFF-ROAD MOTORCYCLES MANUFACTURED 1975-1976

(d) Noise levels (SAE J331a, F-76, F-77, F-50), by displacement and use categories; in-service motorcycles, manufactured 1969-1976, modified exhaust system: Table C-7.

(e) Change in noise levels (SAE J331a, F-76, F-50), referred to original equipment manufacture (OEM), associated with installation of aftermarket exhaust systems and user modifications: Table C-10.

Detailed information on test procedures, test sites, vehicle identification, and aftermarket product identification, is provided in Appendices A, B and C.

4.2 Test Site, Rider, and Vehicle Variables

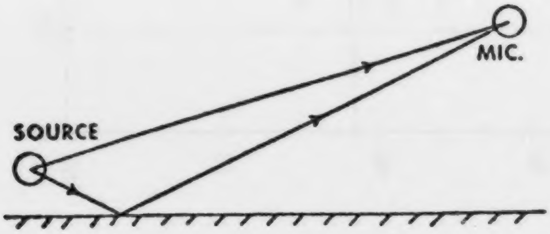
Test Sites

Noise data were obtained at eleven different test sites:

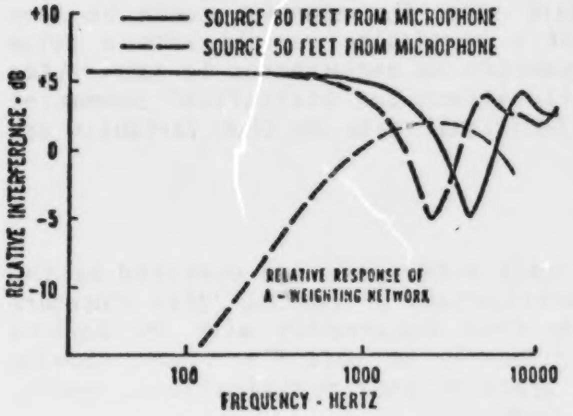
LETTER CODE	LOCATION
A	Argosy Ave., Huntington Beach, California
B	Orange County Fair Grounds, California
C	Daytona Beach, Florida
D	Los Alamitos Naval Air Station, California
E	Pomona, California
F	Houston, Texas
G	St. Petersburg, Florida
H	Albany, Georgia
I	Chapel Hill, North Carolina
J	Suffolk, Virginia
K	Ft. Belvoir, Virginia

Test sites B, D, E, H, and J comply fully with the SAE J331a. Recommended Practice in all respects; the other sites depart in varying degrees (but were the best sites available in the respective local areas), particularly in reference to the requirement for concrete or asphalt ground surfacing between the vehicle path and the microphone. Descriptions and photographs of the test sites are in Appendix B.

In moving vehicle tests, noise reaches the microphone by two paths; the direct path, and a reflected path, as illustrated below:



Direct and reflected noise paths.



Calculated interference of third-octave band noise for a source height of one foot, microphone height of four feet, and a surface reflection of 0.9. 1/

This suggests that noise measurements taken over hard pavement could be either higher or lower than measurements taken over turf or weeds, depending on the spectral content of the noise source. The tabular and graphical data presented in this report include noise measurements taken at all of the test sites. To assess the impact of the non-conforming test sites on the statistical summaries (as shown on the graphical presentations), the statistics of Figure 4-1, SAE J331a vs. displacement were re-computed with data from the non-conforming sites exluded. Results of this comparison are as follows:

Displacement	Data from test sites A thru K	Data from test sites B, D, E, H, J
50-99 cc	$\bar{x}$ = 78.0* σ = 4.44 n = 15	$\bar{x}$ = 78.4 σ = 3.53 n = 11
100-169 cc	$\bar{x}$ = 81.5 σ = 2.95 n = 10	$\bar{x}$ = 80.9 σ = 2.27 n = 7
170-349 cc	$\bar{x}$ = 83.1 σ = 4.49 n = 23	$\bar{x}$ = 83.6 σ = 4.78 n = 19
350-749 cc	$\bar{x}$ = 80.6 σ = 2.99 n = 45	$\bar{x}$ = 81.6 σ = 2.22 n = 25
750 cc and over	$\bar{x}$ = 81.4 σ = 3.96 n = 28	$\bar{x}$ = 82.3 σ = 4.17 n = 15

---

* $\bar{x}$ is the mean noise level, dB
is the standard deviation, dB
n is the number of vehicles in the sample

Source 1 see page 4-29

The foregoing indicates that while site discrepancies could be very important in determining compliance of a particular vehicle with a noise standard, the effect of site discrepancies as encountered in test sites A, C, F, G, I, and K do not materially affect the statistical summaries of the motorcycle noise data base. Additional data on site variables are presented in Appendix C, Table C-15.

Rider Variables

At test site C (Daytona Beach) each motorcycle was operated by the owner of the vehicle; rider weight specifications of the SAE J331a procedure were not observed. The Daytona tests (run concurrently with the Daytona Beach 200 Nationals) were conducted primarily to obtain a sample showing the range of vehicle types, and the types of user modifications, representative of vehicles currently on the road.

At all of the other sites, the rider was within the 165-175 lb. specification. A different rider, properly trained and instructed, was used at each site, but all bikes at a given site were tested by the same rider, except for site B, where three riders were employed.

Vehicle Variables

Production variability data provided by the vehicle manufacturers show that a three-sigma variation of 1.5 dB is common. Samples taken over a six-month period by one manufacturer have shown a total variation range of up to 4 dB. The reason for the latter, which may be a seasonal variation, has not been explained. This suggests that a 2 dB allowance between design and not-to-exceed levels is an absolute minimum, without considering the need for a further allowance in the enforcement situation.

Combined Variables Effect

Factors known or suspected to affect measured noise levels include:

(a) Weather variables affecting noise propagation:

- sunny vs overcast sky
- wind velocity/gradient/direction
- temperature and temperature gradients
- barometric pressure
- humidity

(b) Weather variables affecting engine sound power generation:

- barometric pressure
- temperature
- water vapor pressure
- dry barometric pressure
- dry air density

(c) Manufacturing/assembly/adjustment tolerances affecting engine noise power generation:

- dimensional variations
- spark timing
- fuel/air mixture
- compression variations

(d) Operation variables:

- engine temperature
- entering RPM or speed (SAE J331a)
- rapidity of throttle opening (SAE J331a)
- entering start point (SAE J331a)
- choice of gear selection (SAE J331a)
- closing RPM (SAE J331a and F-76)
- closing point (F-76)

(e) Site variables (site assumed to be in compliance with SAE J331a Recommended Practice):

- surface texture (affecting tire noise)
- porosity (affecting absorption coefficient)

(f) Instrumentation variables:

- acoustical calibrator accuracy
- sound level meter ANSI Type (1 or 2)
- sound level meter crest factor
- speedometer accuracy (SAE J331a)
- tachometer steady-state accuracy (SAE J331a)
- tachometer dynamic lag (SAE J331a and F-76)

Much work has already been done in assessing the effect of many of these variables[1,2]; however, many undefined areas still exist. Although the evaluation of the effects of these variables was outside the scope of the EPA study, quantitative data on the effect of tachometer accuracy, RPM control, and gear selection were obtained in the course of test procedure development.

In addition, in the process of acquiring the noise data base, substantial information was collected on the effects of combined variables. Noise level data comparisons between/among vehicles were made in four groupings:

(a) Different vehicles of the same model tested at different sites;

(b) Different vehicles of the same model tested at the same site;

Notes 1 and 2 see page 4-29

(c) The same vehicle tested at different sites; and

(d) The same vehicle tested at the same site.

The noise level variations (summarized in paragraph 4.3 detailed in appendix C, Table C-14) are smaller than might be expected, considering the extensive range of variability factors. Vehicles of the same model but known to be configured differently (e.g., to meet different standards in different States) have not been included in the comparisons.

4.3 Data Base Statistical Summaries

Noise levels, motorcycles manufactured 1975-1976:

	SAE J331a		F-76	
Displacement	Street*	Off-Road	Street*	Off-Road
50-99 cc	$\bar{x}$ = 78.0	78.8	77.0	76.4
	σ = 4.64	3.35	4.22	1.82
	n = 15	5	11	5
100-169 cc	$\bar{x}$ = 81.5	91.8	79.5	88.7
	σ = 2.95	10.11	2.64	10.4
	n = 10	4	10	3
170-349 cc	$\bar{x}$ = 83.1	88.8	81.95	86.8
	σ = 4.49	4.96	4.94	5.34
	n = 23	16	40	16
350-749 cc	$\bar{x}$ = 80.6	92.3	81.9	
	σ = 2.99	3.79	2.63	
	n = 45	3	40	
750 cc and Over	$\bar{x}$ = 81.4		85.5	
	σ = 3.96		3.47	
	n = 28		18	

Transfer function, F-76 to SAE J331a noise levels (least squares linear regression line):

$y = -2.48 + 0.0066x$ for street* motorcycles
$y = -2.21 * 0.0012x$ for off-road motorcycles

y = F-76 level - SAE J331a level
x = displacement, cc

The F-76 method yields statistical levels 4.1 dB higher than the J331a method at a displacement of 1000 cc, reducing to 1.9 dB lower at 100 cc for the street machines, with a similar trend in the off-road vehicles.

---

*Includes combination street/off-road motorcycles

Constant speed 55 mph noise levels as a function of displacement (least squares linear regression line), motorcycles manufactured 1975-1976:

$$y = 78.65 - 0.0044x$$

y = noise level, dB at 50 ft.
x = displacement, cc

It is of interest to note that this is a downward sloping line with displacement, with motorcycles in the 900-1200 cc range being statistically 3.9 dB quieter than motorcycles in the 100-250 cc range, in the 55 mph operating mode.

Variability in noise level data (from Table C-14); combined effect of site, rider and vehicle variables:

SAE J331a	F-76	F-50
$\bar{x}$ = 0.91	$\bar{x}$ = 1.17	$\bar{x}$ = 1.21
σ = 1.29	σ = 1.58	σ = 1.83
n = 87	n = 69	n = 85

Comparison of motorcycles with modified exhaust systems vs. stock configurations; data from test site C (Daytona Beach) only:

SAE J331a Sound Levels, dB

Motorcycles in stock configuration	Motorcycles with obviously modified exhaust systems
$\bar{x}$ = 84.4	$\bar{x}$ = 93.6
σ = 7.2	σ = 5.2
n = 49	n = 27

The tests at Daytona Beach were timed to coincide with the Daytona Beach 200 National motorcycle events, to permit sampling from a wide range of motorcycle types on a random basis. Vehicles were obtained by open invitation to riders visiting the race and show events; all vehicles offered were tested, and are reflected in the above statistics.

4.4 Aftermarket Exhaust Systems

The EPA study included making contacts with leading motorcycle organizations such as the Motorcycle Industry Council, the Motorcycle Trades Association, the National Motorcycle Dealers Association and many local organizations, to invite a large segment of the aftermarket manufacturers and distributors of replacement exhaust systems to participate in the EPA study. Major meetings and product display shows at Las Vegas and Daytona Beach were attended to explain the objectives of the study, answer questions, obtain basic information about the aftermarket industry, and to solicit active participation by aftermarket manufacturers in a comprehensive test and evaluation program of aftermarket exhaust systems. These meetings were attended by manufacturer representatives from all parts of the United States, thereby giving broad exposure to the program.

Subsequently, formal contacts were made with selected aftermarket manufacturers in the California area, at which time the individual factories were toured, detailed discussions were held with officials in each company, and each company was asked to cooperate in providing replacement exhaust systems to be tested on a family of selected motorcycles.

Companies listed below were contacted either by phone, at a display booth in the aftermarket shows, or visited at their manufacturing facilities:

Action-4*
Alphabets West*
Bassani*
Bates Industries
Butte Industries
Custom Chrome
Cyclone
Dean Maro's Pipelyne
Discojet
Doug. Thorley Headers
Hooker Headers*
Jardine Headers*
J&R Expansion Chambers*
Kook's Custom Headers
MCM Manufacturing*
R.C. Engineering*
S&S Manufacturing*
Santee Industries*
Skyway*
Torque Engineering*
Triple-A Accessories*
Winning Performance Products

Aftermarket Exhaust System Testing Program

An important part of the EPA motorcycle noise study involved noise testing of aftermarket exhaust systems. With the full cooperation and participation of aftermarket exhaust system manufacturers, a comprehensive noise test program was conducted on approximately 107 aftermarket exhaust systems and/or variations. These units were tested on 16 different motorcycles representing the five major motorcycle manufacturers. The testing involved conducting the SAE J-331a and F-76 acceleration tests, and the F-50 stationary test on each of the motorcycles equipped with stock (OEM) exhaust systems, followed by testing with the applicable aftermarket exhaust systems. In addition to testing with the applicable aftermarket and stock exhaust systems, variations were tested such as removing inserts, baffles, fiberglass, and in some cases removing the mufflers altogether, all of which represent forms of modified motorcycles found in circulation.

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*Toured facility

The participating aftermarket exhaust system manufacturers included Santee, Alphabets, Jardine, Hooker, Bassani, S&S, MCM, Yoshimura, Torque Engineering, Winning Performance Products, J&R, Dick's Cycle West, RJS, Kerker, Trabaca and R.C. Engineering. Figure 4-11 shows some of the exhaust systems laid out at the test site prior to installation and testing. Figure 4-12 shows actual installations in progress.

Information on test procedures employed, the test site, and vehicle and aftermarket product identification is provided in the Appendices.

Aftermarket Product Study Results

Detailed noise level data on aftermarket and modified exhaust systems are in Appendix C, and organized as follows:

(a) Listing of motorcycles used in the aftermarket product study; Table C-8.

(b) Listing of aftermarket exhaust systems/components tested, correlated with test vehicle employed; Table C-9.

(c) Noise level data for each configuration designed for the motorcycle on which tested (aftermarket manufacturer disguised); Table C-10.

A summary of the test results follows.

Aftermarket Exhaust Systems as Configured by the Manufacturer

Noise Level	Number of Configurations
Same as OEM	6
Quieter than OEM	9
1 dB higher than OEM	7
2 dB higher than OEM	6
3 dB higher than OEM	4
4-16 dB higher than OEM	50
Total configurations tested	82

Summary: 32 within 3 dB of the OEM
50 4-16 dB higher than the OEM

The above tabulation excludes configurations designated by the manufacturers as "competition" or "racer." Noise levels of configurations so designated were as follows:

dB re OEM
+14
+15
+ 9
+10

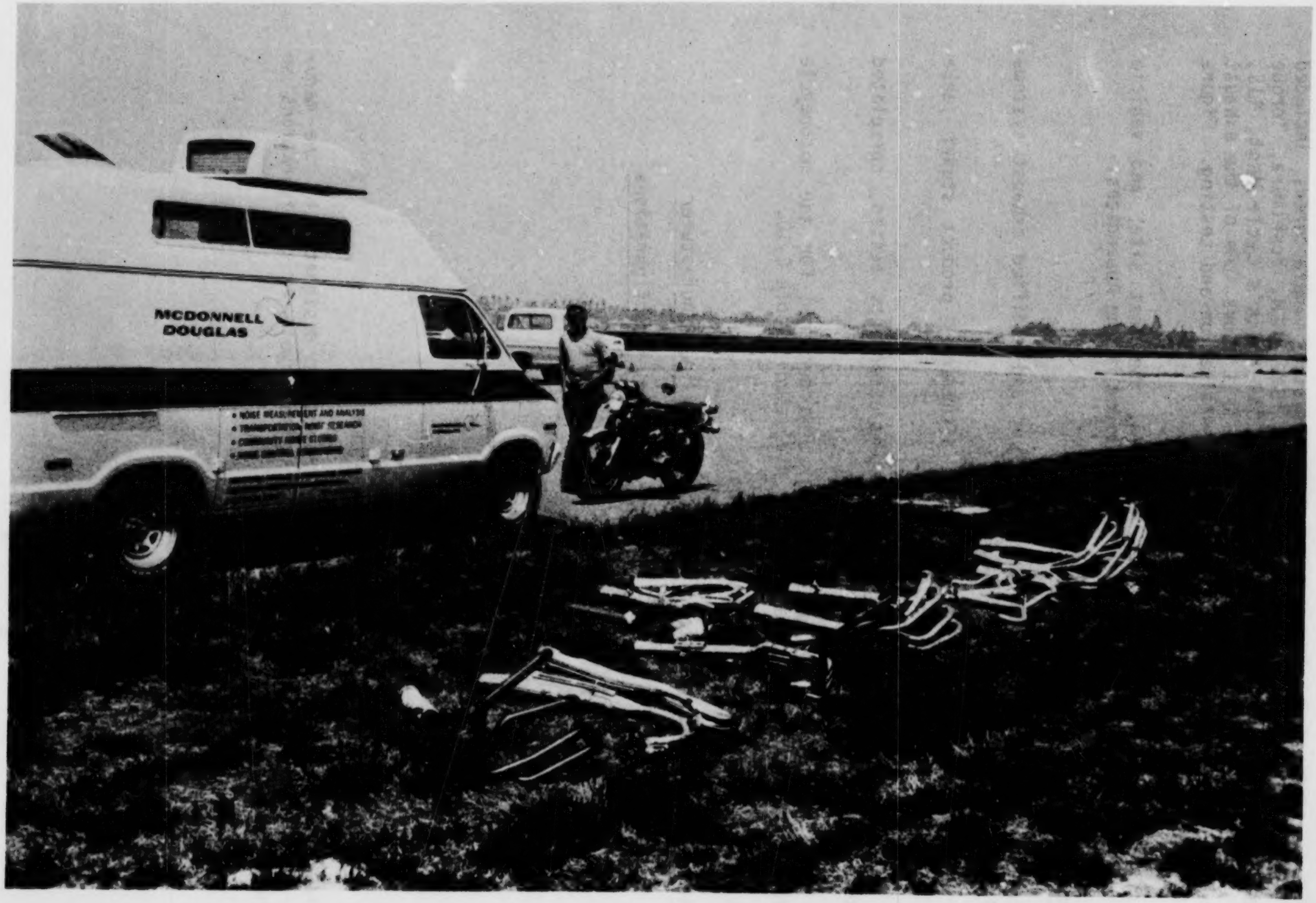
MCDONNELL
DOUGLAS
• NOISE MEASUREMENT AND ANALYSIS
• TRANSPORTATION NOISE RESEARCH

FIGURE 4-11 AFTERMARKET EXHAUST SYSTEMS TO BE TESTED

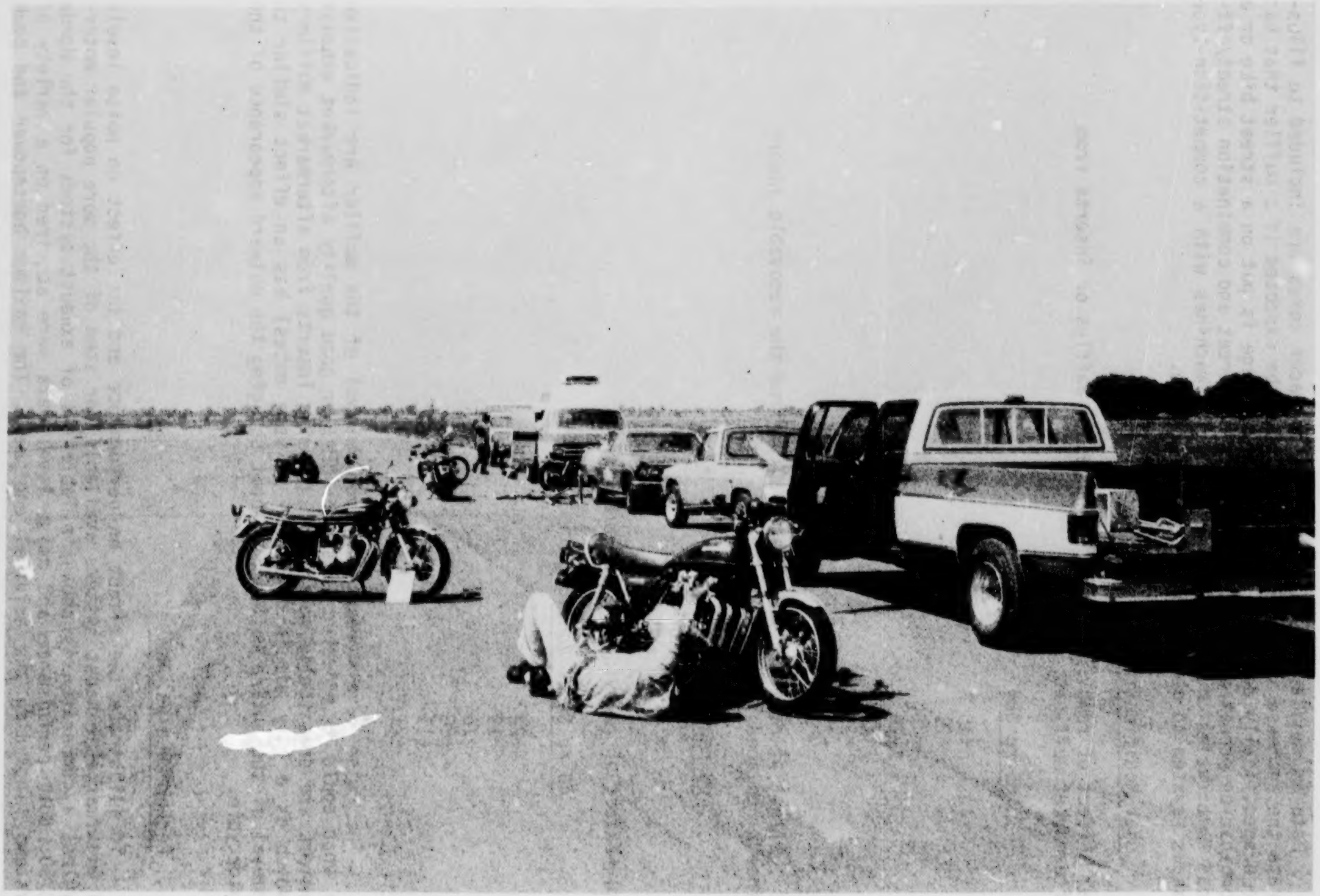

FIGURE 4-12 INSTALLATION OF AFTERMARKET EXHAUST SYSTEMS PRIOR TO TESTING

Data on mufflers with competition or racer cores are included to illustrate the increase in noise level that could be expected if a muffler that has been specifically designed for competition usage is put on a street bike or a combination street/off-road bike. Owners of street and combination street/off-road motorcycles are known to modify their machines with a competition-type exhaust system to obtain increased performance.

User Modifications

(a) Effect of removing the interchangeable baffles or inserts from aftermarket mufflers:

dB re OEM
+15
+21
+22
+29
+21
+15
+21

(b) Effect of removing the glass blanket from the removable insert (insert replaced):

dB re OEM
+ 4

(c) Effect of removing the OEM muffler:

dB re Stock Config.
+22
+19
+16
+20
+19
+21

The noise levels resulting from removal of the muffler are indicative of what could be expected if stock (OEM) or good quality aftermarket exhaust systems are drastically modified. Removing inserts from aftermarket mufflers (which is a very simple operation on some makes) has an effect similar to removal of the entire muffler, without changing the outward appearance of the motorcycle.

Performance vs. Noise

To illustrate the effect on performance and the effect on noise levels of aftermarket exhaust systems available for some of the more popular motorcycles, a comparison is shown in Table 4-1 of exhaust systems for the Honda CB750. Both performance and noise level data were acquired on a variety of systems, including the original equipment. The maximum horsepower and peak torque performance data on this particular motorcycle were obtained on a dynamometer, whereas the noise measurements were obtained using the SAE J331a vehicle acceleration type test procedure. It is apparent from the data that the aftermarket exhaust systems designed to increase performance over the original equipment also significantly increase the noise level. Conversely, the quieter aftermarket exhaust systems that approach the noise levels produced by the OEM system, have a somewhat adverse effect on vehicle horsepower although the peak torque is somewhat enhanced. It has been pointed out by some manufacturers that the effect of peak torque occurring at a lower RPM than the OEM unit gives the feel of greater "pulling" power, therefore leading to the conclusion that a particular exhaust system has improved the motorcycle performance.

Another important point illustrated in Table 4-1 is the availability of different inserts or cores with the same baseline muffler. Several manufacturers offer exhaust systems with a variety of removable cores or adjustable vanes that can be added or decreased in number to obtain the desired end-result in performance and noise level. This type of product is offered for motorcyclists who have combination street/off-road bikes which are used for competitive events or off-road activities in which increased performance is important. The adjustable-vane type mufflers have been designed to accommodate a range of motorcycles Manufacturers state that they purposely provide mufflers with two inserts: one for use in an off-road situation, which will increase performance significantly, but as a by-product will also increase the noise level, and a second insert which is to be used by the motorcyclist when he is to ride that motorcycle on the street With a simple change, the motorcyclist can remove the noisier high performance insert and replace it with the street-legal type insert which will comply with existing noise limits.

4.5 Noise Levels at the Operator and Passenger's Ear Position

In order to assess potential benefits in hearing risk to motorcycle operators from reducing motorcycle noise emissions, EPA conducted a study of motorcycle noise levels at the operator and passenger ear positions. The details of the study program are described in Appendix E. Measurements were made on three large motorcycle models (Honda 750, BMW, Harley-Davidson) in various operating modes. Measurements were made with the motorcycle stationary, on a dynometer and under moving conditions. In addition, measurements were made with bare head, head covered with a cap to reduce wind effects, and inside a helmet. An attempt was made to distinguish wind turbulence and motorcycle (only) contributions.

The information presented in the Appendix shows that wind-induced noise (turbulence caused by wind flowing by the ear) is an extremely complex pheno menon. It depends not only on wind speed but vehicle and operator geometry and head attitude. In addition, it appears that operator-induced turbulence increases passenger exposure. The influence of helmets on operator exposure is another extremely complex phenomenon, again depending on geometery and attitude. Both enhancement and attenuation of noise levels compared to bare head levels were noted in different frequency bands and for different head attitudes. It appears that helmet-induced turbulence may increase operator noise exposure for some helmet geometries.

Table 4-1

COMPARISON OF AFTERMARKT EXHAUST SYSTEMS FOR HONDA CB750

NOISE LEVEL AND PERFORMANCE

EXHAUST SYSTEM	NOISE LEVEL (dB) (SAE J331a)	MAX. H.P.	Peak Torque
HONDA 750 (OEM)	81 dB	57.67 @ 8500 RPM	36.25 @ 8000 RPM
BASSANI (RACING) 4:1	91		
BASSANI SMALL 4:1	81	55.28 @ 8000	36.12 @ 7000
RJS QUIET CORE	82		
RJS STOCK CORE	87		
DICK'S CYCLE WEST	82	56.89 @ 8500	37.00 @ 6500
TRABACA 2:1	89	47.52 @ 7500	35.25 @ 6500
J&R WITH STREET CORE	84	56.0 @ 8000	37.06 @ 6500
J&R WITH COMPETITION CORE	91	60.3 @ 8500	39.25 @ 6500
HOOKER 4:1	89	57.92 @ 8500	38.62 @ 6500
TORQUE ENGINEERING	83	56.75 @ 8000	37.93 @ 6500
JARDINE	82	53.6 @ 8000	37.00 @ 6500
R.C. ENGINEERING	87	55.6 @ 8500	35.75 @ 7500
ALPHABETS	83.5	56.6 @ 8500	38.43 @ 6500
WINNING	88	59.38 @ 8500	37.68 @ 7500

SOURCE: Street Bike - July 1976
"Honda 750 Header Shoot-Out," Jeff Peck

At this time, motorcycle (alone) noise level (absent wind and helmet effects) appears to be the best measure for assessing motorcycle operator noise impact. Both dynamometer and moving runs indicated that the operator noise levels under F-76a acceleration conditions were about 100 dB for the motorcycles tested (SAE J331a valves (50 feet)--Honda: 81 dB, BMW: 81 dB, Harley-Davidson: 84 dB. Wind noise was below 90 dB for all speeds up to 45 mph except for the trailing ear when a motorcyclist without a helmet inclined his head 45 degrees away from the line of travel It can be concluded that under rapid acceleration conditions, for the motorcycles tested, motorcycle (alone) contributions would outweigh wind noise for a helmeted operator.

The extent to which operator ear noise levels would decline as fifty-foo noise levels declined in response to wayside regulations cannot be confidently predicted. However, since attention must be given to intake and mechanical noise (both nearer the operator's ear than the exhaust noise source), some reduction is to be expected.

REFERENCES

1. Hillquist, R. K. and Bettis, R. A., Measurement of Automotive Pass-by Noise, paper presented at the SAE Automotive Engineering Congress, Detroit, Michigan, January 10-14, 1972.

2. Hemdal, John F., et al., A Study of Repeatability at Motor Vehicle Noise Measurement Sites, Environmental Research Institute of Michigan, 1974.

SECTION 5

EVALUATION OF EFFECTS OF MOTORCYCLE NOISE ON PUBLIC HEALTH AND WELFARE

SECTION 5

EVALUATION OF EFFECTS OF MOTORCYCLE NOISE ON PUBLIC HEALTH AND WELFARE

5.1 Introduction

The purpose of this section is to assess, in quantitative terms, the health and welfare impact of the noise emitted by motorcycles, and the benefits or reductions in this impact to be expected from a regulation limiting the noise emissions from newly manufactured motorcycles. Presented in this analysis are predictions of the potential health and welfare benefits of selected noise control options that cover a wide range of possible regulatory programs for motorcycles.

Because of inherent differences in individual responses to noise, the wide range of situations and environments which relate to motorcycle noise generation, and the complexity of the associated noise fields, it is not possible to precisely examine all situations of community exposure to motorcycle noise. In this predictive analysis, certain stated assumptions have been made in order to approximate typical, or average, situations. The order of magnitude of the population that may be affected for each regulatory option is determined through statistical analysis. Some uncertainties with respect to individual cases or situations may remain.

5.1.1 Effects of Noise on People

The phrase "health and welfare," as used in this analysis and in the context of the Noise Control Act, is a broad term. It includes personal comfort and well-being and the absence of mental anguish, disturbances and annoyance, as well as the nonoccurrence of clinical symptoms such as hearing loss or demonstrable physiological injury (Reference 1). In other words, the term applies to the entire range of adverse effects that noise can have on people.

Improvements in public health and welfare are regarded as benefits of noise control. Public health and welfare benefits may be estimated both in terms of reductions in noise exposure and, more meaningfully, in terms of reductions in adverse effects. This analysis first estimates motorcycle noise exposure (numbers of people exposed to different noise levels), and then translates this exposure into potential impacts on the community.

People are exposed to noise from motorcycles in a variety of situations. Some examples are:

1. Inside a home, office or workplace
2. Outdoors at home, or in commercial and industrial areas

3. As a pedestrian or in transit in other vehicles
4. As a participant in recreational activities
5. As a motorcycle operator or passenger

Noise affects people in many ways, although not all noise effects will occur at all levels. Noise associated with motorcycles may or may not produce the effects mentioned below, the extent to which depends on duration of exposures and specific noise exposure situations.

The best-known noise effect, noise-induced hearing loss, is generally not a problem for a person with occasional exposure to traffic noise. A characteristic of noise-induced hearing loss is that it first occurs in the high-frequency area of the auditory range which has some importance for the understanding of speech. As a noise-induced hearing loss further develops, the sounds which lend meaning to speech become less and less discriminable. Eventually, while utterances are still heard, they become merely a series of low rumbles, and the intelligibility is lost. Noise-induced hearing loss is a permanent loss for which hearing aids and medical procedures cannot compensate.

Exposure to noise can cause stress. The body has a basic, primitive response mechanism which automatically reacts to noise as if to a warning or danger signal. A complex series of bodily reactions (sometimes called the "flight-or-fight" response) takes place; these reactions are beyond conscious control. When noise intrudes, these reactions can include elevation of blood pressure, changes in heart rate, secretions of certain hormones into the bloodstream, changes in digestive processes, and increased perspiration on the skin.

This stress response occurs with individual noise events, but it is not known yet whether the reactions seen in the short term become, or contribute to, long-term stress disease such as chronic high blood pressure.

Some of this stress response is believed to be reflected in what people express as "annoyance", "irritation", or "aggravation" and which the Agency has termed "general adverse response". Accordingly, this analysis estimates the generalized adverse responses of people to environmental noise. To the extent that physiological stress and verbalized annoyance are related, the "general adverse response" quantity is considered to be one metric for indicating the magnitude of human stress response.

The general adverse response relationship to noise levels is also seen as representing, in part, another area of noise effects: activity interference. There is considerable scientific data that demonstrate that noise interferes with many important daily activities such as sleep and verbal communication (Reference 2). In expressing the causes of annoyance to noise, people often report that noise interferes with sleeping, relaxing, concentration, TV and radio listening, and face-to-face and telephone communications. Thus, the general adverse response quantity is considered an appropriate metric to indicate the severity to which noise interferes with everyday human activities.

5.1.2 Measures of Benefits to Public Health and Welfare

People are exposed to noise generated from motorcycles both at and away from their residences. In general, it is anticipated that a reduction of noise emitted from motorcycles will result in the following types of benefits:

1. Reduction in average traffic noise levels and associated cumulative long-term impact upon the exposed population.

2. Fewer human activities disrupted by individual, intense or intruding noise events.

3. General improvement in the quality of life, with quiet as a national resource.

The general approach taken in this health and welfare regulatory analysis is to estimate the adverse effects of motorcycle noise on the U.S. population, and then quantitatively evaluate the potential benefits resulting from the reduction of noise from motorcycles in terms of percentage reductions in adverse impact.

Estimates of traffic noise levels are presented in terms of the noise levels associated with typical motorcycle passbys. These estimates are derived by considering traffic mixes within different populated land areas. Possible reductions in average traffic noise levels from current conditions (i.e., without noise emission regulations for motorcycles) are presented for several regulatory options for new motorcycles, taking into account probable noise emission reductions of other traffic noise sources (References 3 and 4). Projections of the population adversely impacted, as well as the relative reductions in impact (benefits) from current conditions, are determined from the estimated reductions in average traffic noise levels.

However, estimating nationwide impact in terms of average urban traffic noise levels is not, in and of itself, totally indicative of the severity or extensiveness of the motorcycle noise problem. The analysis does not fully describe individual disturbances or the extreme annoyance caused by single motorcycle passbys in various environmental situations. This is because annoyance or other responses to noise frequently depend on the activities and locations of the people when exposed to such noise. Thus, average traffic noise levels do not account for the more disruptive and annoying peak noise intrusions produced by individual motorcycle passbys (frequently referred to as "single events"). Therefore, additional potential benefits should result from the reduced noise levels associated with these single events. These benefits are discussed in terms of the potential interference with people's activities. Sleep interference and speech interference are considered in this analysis as indicators of potential activity interference and the associated adverse impact of motorcycle noise.

The following analysis presents numeric values which represent both the numbers of people exposed to motorcycle noise and the degree to which they are potentially impacted. Also presented are relative percentage reductions in impact from 1980 conditions. This analysis relies primarily on relative percent reductions in noise impact as a measure of benefit. The relative reductions in impacts are considered accurate indicators of what might be expected from the imposition of noise emission standards. For example, while it may not be possible to characterize completely the extensiveness and severity of the noise impact of current motorcycle operations, relative reductions can be accurately calculated and are used for comparing various regulatory alternatives.

5.1.3 Regulatory Schedules

The health and welfare analysis carried out for motorcycles examined the potential benefits of reducing motorcycle noise based upon a broad range of regulatory options. The regulatory options shown in Table 5-1 represent those options that were considered in arriving at the final regulatory levels and effective dates. Option Q (an idealized case) represents the quieting of motorcycles to a level 10 dB below the most stringent regulatory option. This option is included for comparison purposes only to indicate an upper limit of potential benefits.

5.2 Description of Traffic Noise Impact

This analysis presents projections of average traffic passby noise levels for scenarios that include both urban street traffic and highway traffic. Note that the adverse impact from traffic noise is primarily due to traffic on urban streets as opposed to highways and freeways.

As presented in Figure 5-1, the number of people exposed to outdoor noise levels that are greater than L_{dn}* of 55 dB dominated by urban street traffic noise is significantly higher than the number exposed to highway and freeway traffic noise -- 78 million as opposed to 17 million. Thus, reducing urban street traffic noise will benefit significantly more people than will similar reductions in highway traffic noise.

5.2.1 Street Motorcycles

In this section of the health and welfare analysis, current street motorcycle sound levels, as well as sound levels under various possible noise emission regulations on motorcycles that are ridden on streets and highways, are examined. This includes both street and dual-purpose bikes. (Motorcycles that are ridden off-road are examined separately in Sections 5.9 through 5.12).

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* L_{dn} is the day-night sound level expressed in decibels. This is discussed in more detail in Section 5.3.2.

TABLE 5-1

REGULATORY OPTIONS ANALYZED FOR STREET MOTORCYCLES

Option Number	Effective Date						
	1982	1984	1985	1987	1990	1991	1996
1	--	--	BASELINE (NO REGULATION)			--	--
2	83	--	--	--	--	--	--
3	83	80	--	--	--	--	--
4	83	--	80	--	--	--	--
5	83	80	--	78	--	--	--
6	83	80	--	--	78	--	--
7	83	--	80	78	--	--	--
8	83	--	80	--	78	--	--
9	83	80	--	78	--	75	--
10	83	--	80	--	78	--	75
Q*	65	--	--	--	--	--	--

Not-to-exceed sound levels in decibels (A-weighted) as measured by the Federal test procedure. Production levels are assumed to be 2.5 dB lower than these regulatory levels, as discussed in Section 5.2.1.2.

*Option Q is set 10 dB below the most stringent regulatory option. It is an idealistic option intended for comparison purposes only.

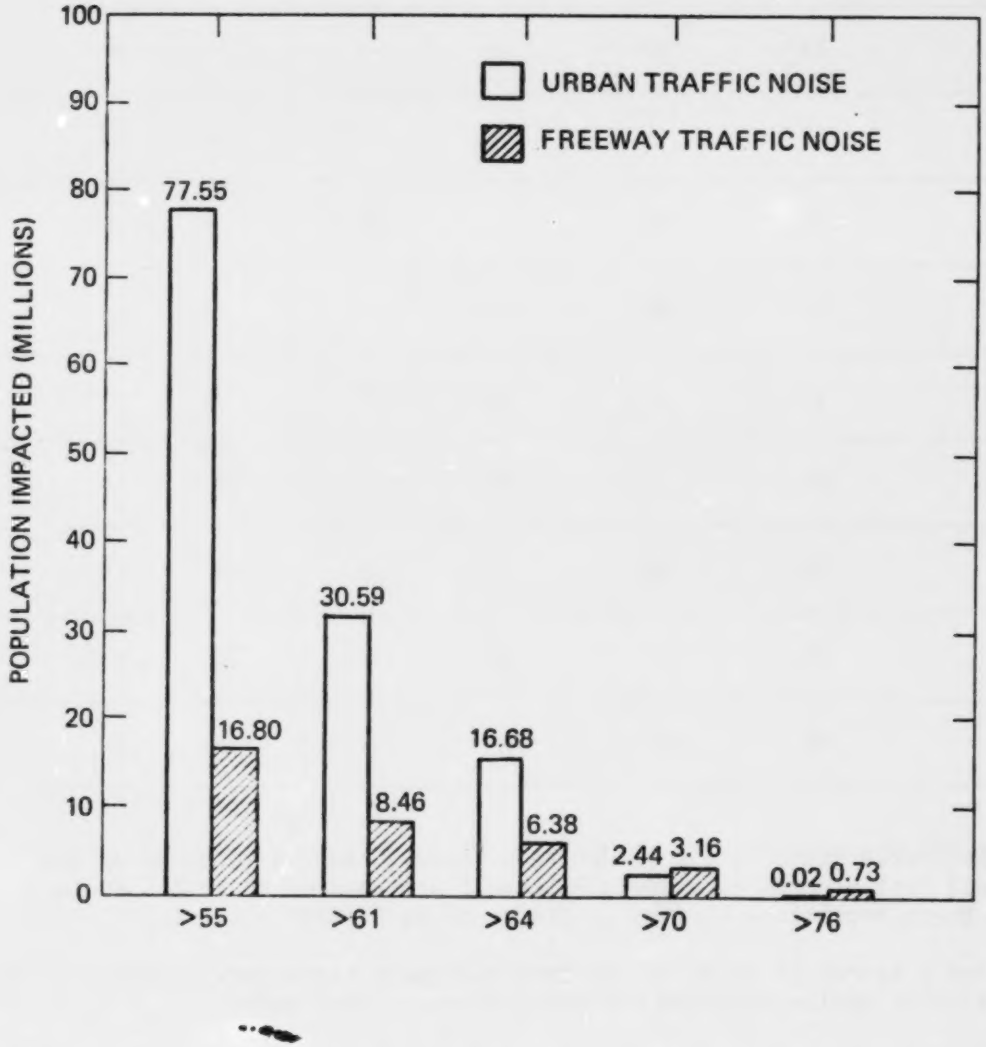


FIGURE 5-1 ESTIMATED NUMBER OF PEOPLE IN RESIDENTIAL AREAS CURRENTLY SUBJECTED TO TRAFFIC NOISE ABOVE L_{dn} = 55 dB

5.2.1.1 Current Street Motorcycle Sound Levels

A statistical representation of stock motorcycle sound levels, based on the data in Appendix C, is presented in Figure 5-2. These data are the maximum sound levels as measured by the SAE J-331a test procedure. This procedure is representative of very rapid acceleration from 30 mph (full-throttle, high engine speed). The maximum sound levels as measured by SAE J-331a procedure can be adjusted to account for more commonly encountered acceleration modes (partial-throttle and moderately high engine speed). As discussed in Section 3, sound levels as measured by the regulatory test procedure are assumed to be statistically equivalent to SAE J-331a levels. Cruise sound levels are based on steady-state operation at various constant speeds.

The data in Figure 5-2 were developed from noise measurements of 200 unmodified motorcycles that were selected to be representative, by year of manufacture and type, of the national population of motorcycles in-service licensed for street use in 1975. Additional noise measurements (discussed in Appendix C) of 160 newly manufactured (1975-1976) street and dual-purpose motorcycles yielded sound levels that did not differ significantly from the distribution shown in Figure 5-2. Hence, Figure 5-2 is considered to be applicable to motorcycles currently on the road as well as to present-day newly manufactured motorcycles.

According to a national survey (Reference 5), at least 12 percent of street motorcycles and dual-purpose motorcycles (treated in this analysis as street motorcycles), and 26 percent of off-road motorcycles have modified exhaust systems. (In Los Angeles and San Francisco, these percentages were higher, approximately 15, 13, and 47 percent for street, dual-purpose, and off-road, respectively.) In general, modification of a motorcycle exhaust system significantly increases the motorcycle's sound level. Although other types of modifications, such as intake modification, may also affect the sound level of a motorcycle, exhaust system modifications are typically the most noticeable form of motorcycle noise tampering.

In this analysis, statistics are developed by using several different assumptions on the incidence of modified motorcycles. The current incidence, unchanged by Federal regulation (12%), and two lower incidences (7% and 3%) are modeled for street motorcycles to reflect the expected reduction of exhaust modifications. Eliminating motorcycle modifications entirely, however, is not considered to be feasible with even the most vigorous commitment to noise enforcement by Federal, state , and local governments. Reduction of modified motorcycles to about half the current incidence (7% of the population) is the expected reduction through Federal regulation alone. Reduction to about one quarter of the current incidence (3%) is considered to be the reduction achievable from a combination of Federal regulation and vigorous state and local enforcement programs.

The sound levels of 19 known exhaust-modified (noncompetition) motorcycles are plotted in Figure 5-3. The best fit of a normal distribution to the data is indicated by the straight line. In comparison with the SAE J-331a test results for unmodified motorcycles shown in Figure 5.2, it can be seen

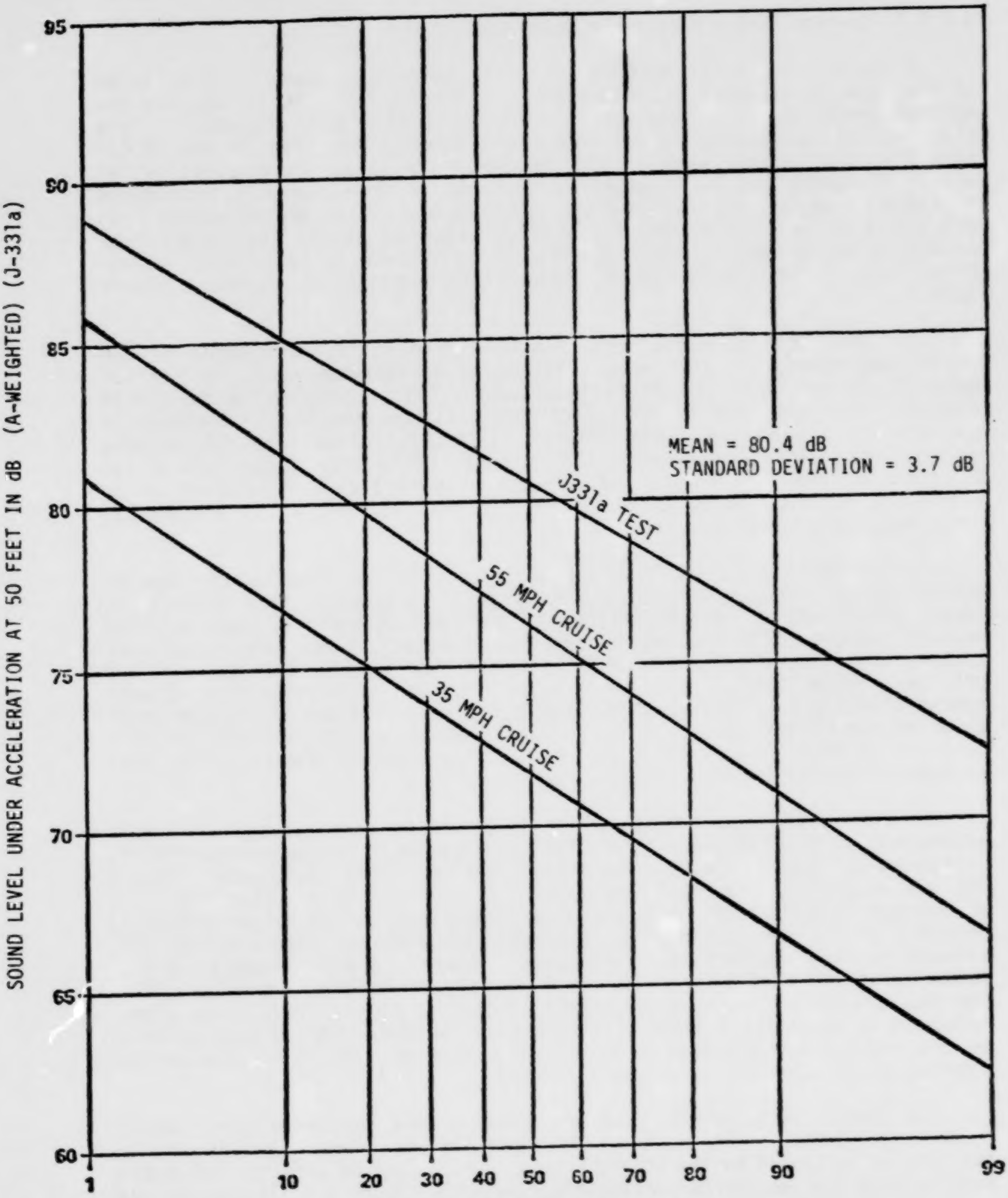
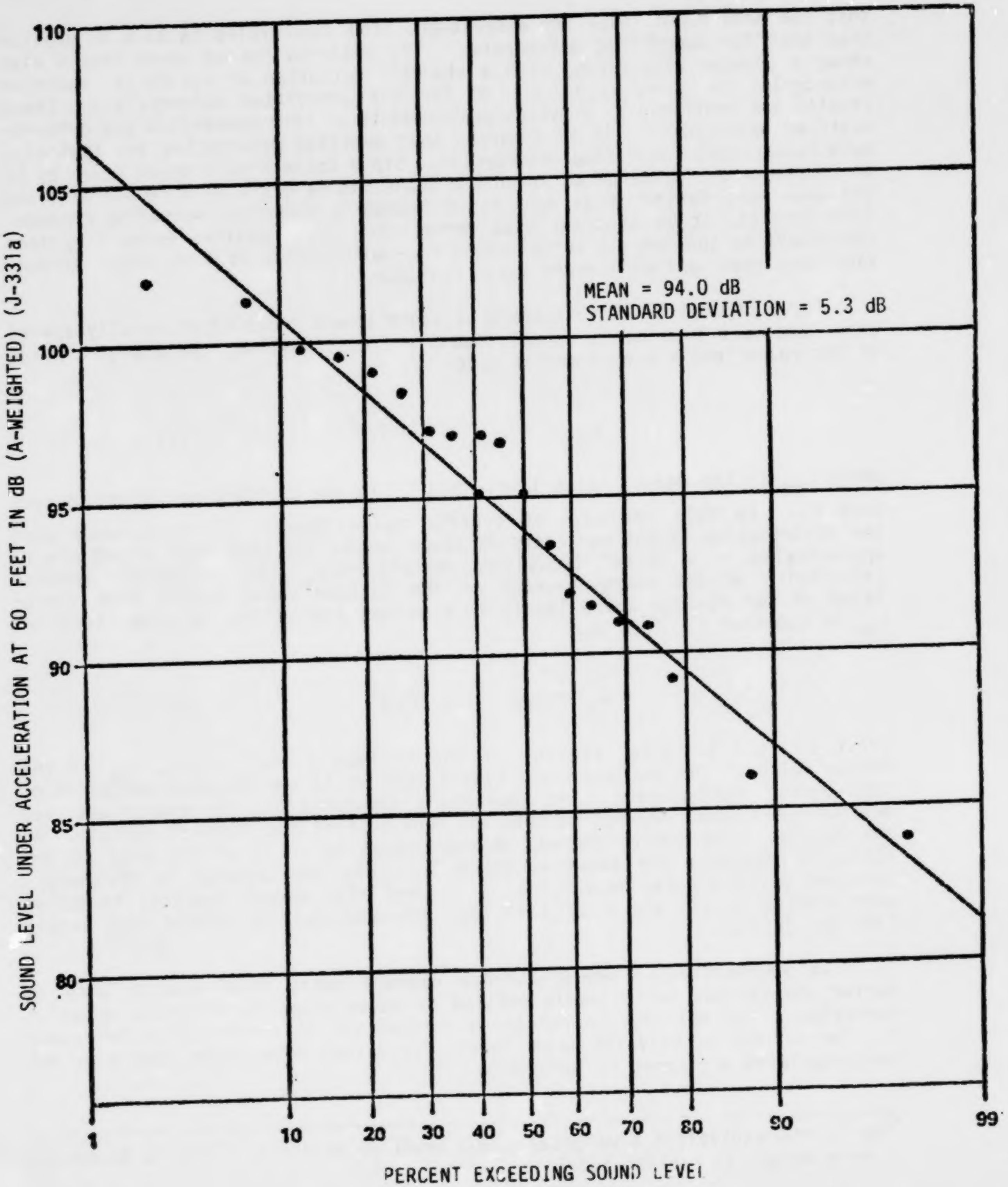


FIGURE 5-2 PERCENT OF UNMODIFIED STREET MOTORCYCLES WICH EXCEED ANY GIVEN SOUND LEVEL.

SOURCE: APPENDIX C



SOURCE: APPENDIX C

FIGURE 5-3 PERCENT OF MODIFIED MOTORCYCLES WHICH EXCEED ANY GIVEN A-WEIGHTED SOUND LEVEL

that the mean sound level for exhaust-modified motorcycles is 13.6 dB greater than that for unmodified motorcycles. The distribution of sound levels also shows a greater dispersion, with a standard deviation of 5.3 dB for modified motorcycles as compared to 3.7 dB for the unmodified motorcycles. These results are confirmed by previous measurements of both unmodified and exhaust-modified motorcycles. It is apparent that modified motorcycles are typically much louder than unmodified motorcycles. Since increasing a sound level by 12 dB increases the distance at which the sound can be heard by a factor of 4 and the area by a factor of as much as 16 (assuming spherical spreading propagation losses), it is apparent that motorcycles with modified exhaust systems contribute to the overall noise impact from motorcycles in much larger proportion than their actual numbers would indicate.

For a population of instantaneous sound levels observed at equally spaced time intervals that has a normal (Gaussian) distribution, the energy-average of the sound levels over time* is given by:

$$L_{eq} = L_{50} + 0.115\sigma^2 \qquad (1)$$

where L_{50} is the median noise level, and is the standard deviation (Reference 6). In this analysis of traffic noise impact, it is assumed that the distribution of maximum roadside sound levels for each type of vehicle is approximated by a normal (Gaussian) distribution. This assumption permits calculation of the energy-average of the maximum sound levels from median value of the maximum sound levels in a manner similar to the computation of L_{eq} in Equation 1. That is:

$$L_a = L_{50} + 0.115\sigma^2 \qquad (2)$$

where L_a is the energy-average of the maximum sound levels, L_{50} is the median value of the maximum sound levels, and σ is the standard deviation of the maximum sound levels. As Equation 2 demonstrates, the energy-averaged maximum sound level depends on both the median level and standard deviation of the levels. The energy-average maximum sound levels that are used in the following analysis are shown in Table 5-2. In the computation of energy-averaged maximum noise levels, it is assumed that normal (partial throttle) acceleration levels are 3 dB less than the measured SAE J-331a test levels (see Appendix G).

The representative energy-average maximum noise level can be used to derive the various noise levels emitted by motorcycles in different modes of operation. The methodology for these derivations is contained in Reference 7. The current or baseline noise levels for street motorcycles that have not been regulated are shown in Table 5-3.

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*L_{eq} is the equivalent A-weighted sound level in decibels. This is discussed in more detail in section 5.3.1.

TABLE 5-2

A-WEIGHTED MAXIMUM SOUND LEVELS IN DECIBELS FOR MOTORCYCLES IN USE
(CURRENTLY AND IN THE NEAR FUTURE, IF UNREGULATED)

	35 mph Cruise	Full-Throttle Acceleration (J-331a) (median level)	Representative Acceleration (J-331a - 3 dB) (median level)	Standard Deviation	Energy-Averaged Representative Acceleration (from Eq 2)
Unmodified Motorcycles Designed for Street Use	71.5	80.4	77.4	3.7	79.0
Exhaust-Modified Motorcycles	84.0	94.0	91.0	5.3	94.2

SOURCE: Appendices C & G. The 35 MPH cruise noise level for modified motorcycles is assumed to be 10 dB lower than the J331a noise level based on the studies discussed in Appendix G.

TABLE 5-3

BASELINE A-WEIGHTED NOISE LEVELS (IN DECIBELS) FOR VARIOUS MODES OF OPERATION OF STREET MOTORCYCLES

Mode of Operation	Unmodified Motorcycles	Modified Motorcycles
Acceleration		
0-20 mph	72.3	87.5
0-30 "	73.9	89.1
0-40 "	74.4	89.6
0-50 "	74.7	89.9
0-60 "	74.9	90.1
Deceleration		
20-0 mph	61.5	75.7
30-0 "	65.9	80.1
40-0 "	69.0	83.2
50-0 "	71.4	85.6
60-0 "	73.4	87.6
Cruise		
< 25 mph	66.9	81.1
24-34 "	71.3	85.5
35-44 "	74.4	88.6
45-54 "	76.9	91.1
> 55 "	78.9	93.1
Idle	58.9	72.0

5.2.1.2 Noise Emission Levels of Regulated Street Motorcycles

In order to predict the effect that a motorcycle noise emission regulation will have on actual motorcycle noise emissions, some assumptions must be made as to the changes that would occur in the sound levels presented in Figures 5-2 and 5-3 (for unregulated motorcycles) due to a particular regulatory standard. It is expected that to comply with a Federal noise regulation, manufacturers will produce motorcycles with average sound levels about 2.5 dB lower than the regulatory limits to account for production and testing variabilities (see Chapter 6). For modeling purposes, the production level is assumed to be the median value for a distribution of maximum sound levels for new motorcycles having a standard deviation of 2.5 dB.

Using the above stated assumptions, future production motorcycle sound levels are estimated for the different regulatory options as shown in Figure 5-4. The statistical distributions of sound levels for the regulatory options illustrated in Figure 5-4 are developed on the assumption that manufacturers will not further quiet motorcycles which already meet noise standards. Anticipated noise emission levels for each mode of operation of motorcycles regulated to levels of 83 dB, 80 dB, 78 dB, and 75 dB are shown in Table 5-4. These representative noise emission levels under each operational mode were derived according to the procedures of Reference 7.

After implementation of a noise emission regulation for motorcycles, it is expected that as more and more older unregulated motorcycles are replaced by new regulated motorcycles, the population averaged acceleration sound levels will also be reduced over time. For example, suppose a regulation was promulgated which provided that no new motorcycle for street use could exceed 80 dB, according to the SAE J-331a test procedure. The motorcycles above this sound level, which comprise the "loudest" 56 percent of the unmodified street-use motorcycles shown in Figure 5-4, would eventually disappear as quieter motorcycles replace older models. Eventually a new distribution would be formed in which no unmodified street-use motorcycle would exceed the 80 dB standard as measured by the SAE J-331a test, and the mean level would decrease accordingly.

5.2.1.3 Motor Vehicle Noise

To better identify those circumstances in which street motorcycles cause significant noise impact, it is necessary to relate motorcycle sound level distributions for other traffic vehicles.

Table 5-5 presents the current (1979) levels of all vehicles in the traffic stream for several modes of operation. Seven categories of light vehicles and automobiles are regulated with respect to noise. The noise emission levels presented for the two categories of trucks represent the levels associated with the 83 dB noise regulation, which became effective in 1978. By 1982, medium and heavy trucks will be required to meet a regulatory limit of 80 dB, as measured by the SAE J-336b test procedure. The levels presented for buses are unregulated levels, although they, too, will be regulated to lower levels in the near future.

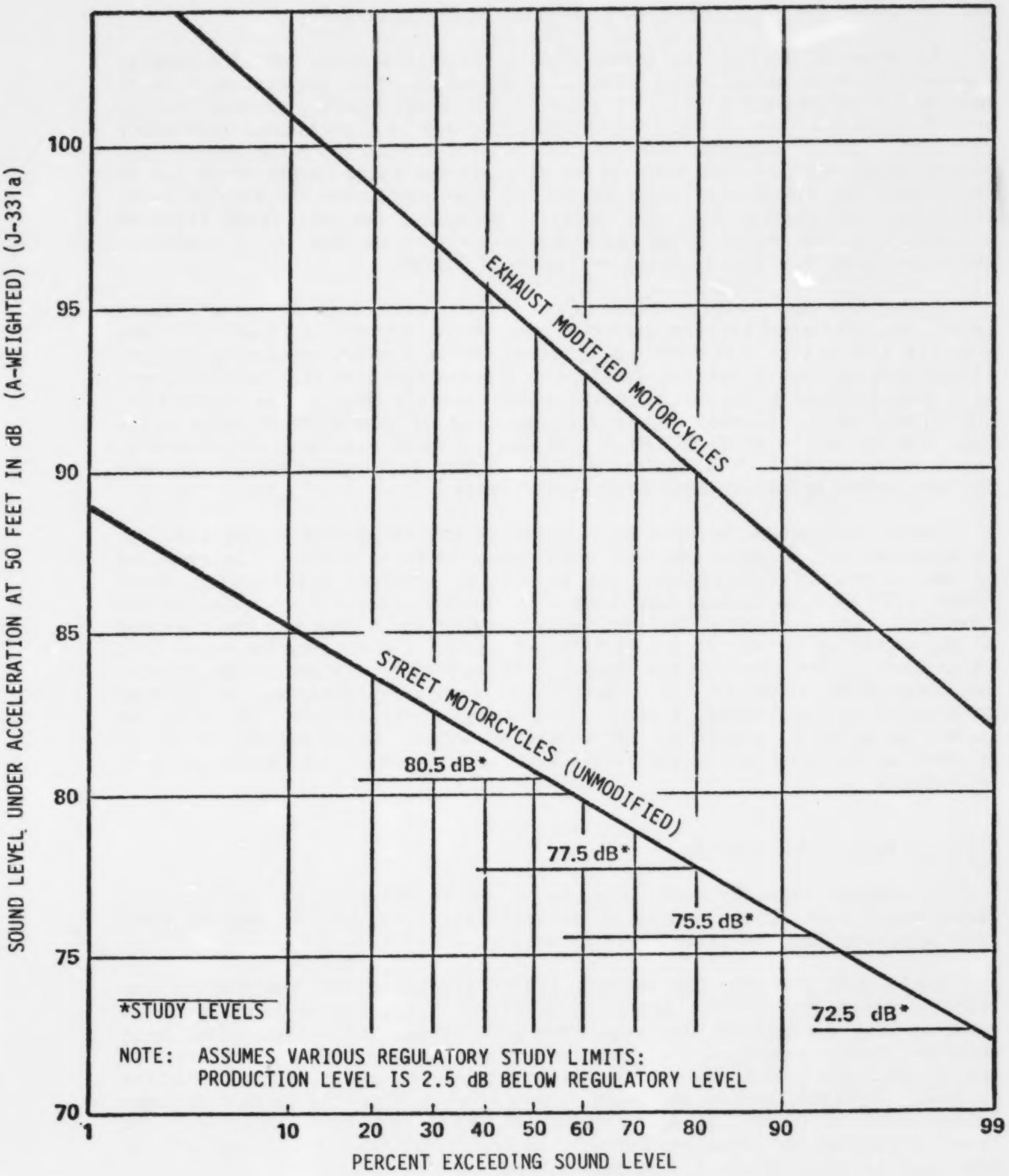

FIGURE 5-4 STATISTICAL DISTRIBUTION OF ACCELERATION SOUND LEVELS OF STREET MOTORCYCLES

TABLE 5-4

IN-USE A-WEIGHTED NOISE EMISSION LEVELS (IN DECIBELS) FOR REGULATED AND UNREGULATED MOTORCYLES

Unmodified Motorcycles

Acceleration Mode

Mode of Operation	No Regulation	83 dB	80 dB	78 dB	75 dB
0-20 mph	72.3	71.5	68.5	66.5	63.5
0-30 "	73.9	73.1	70.1	68.1	65.1
0-40 "	74.4	73.6	70.6	68.6	65.6
0-50 "	74.7	73.9	70.9	68.9	65.9
0-60 "	74.9	74.1	71.1	69.1	66.1

Deceleration Mode

Mode of Operation	No Regulation	83 dB	80 dB	78 dB	75 dB
20-0 mph	61.5	60.7	57.7	55.7	52.7
30-0 "	65.9	65.1	62.1	60.1	57.1
40-0 "	69.0	68.2	65.2	63.2	60.2
50-0 "	71.4	70.6	67.6	65.6	62.6
60-0 "	73.4	72.6	69.6	67.6	64.6

Cruise Mode

Mode of Operation	No Regulation	83 dB	80 dB	78 dB	75 dB
<25 mph	66.9	66.1	63.1	61.1	58.1
24-34	71.3	70.5	67.5	65.5	62.5
35-44	74.4	73.6	70.6	68.6	65.6
45-54	76.9	76.1	73.1	71.1	68.1
>55	78.9	78.1	75.1	73.1	70.1

Idle Mode

Mode of Operation	No Regulation	83 dB	80 dB	78 dB	75 dB
	58.9	58.3	55.3	53.3	50.3

Modified Motorcycles

Acceleration Mode

Mode of Operation	No Regulation
0-20 mph	87.5
0-30 "	89.1
0-40 "	89.6
0-50 "	89.9
0-60 "	90.1

Deceleration Mode

Mode of Operation	No Regulation
20-0 mph	75.7
30-0 "	80.1
40-0 "	83.2
50-0 "	85.6
60-0 "	87.6

Cruise Mode

Mode of Operation	No Regulation
<25 mph	81.1
25-34 "	85.5
35-44 "	88.6
45-54 "	91.1
>55 "	93.1

Idle Mode

Mode of Operation	No Regulation
	72.0

TABLE 5-5
BASELINE VEHICLE A-WEIGHTED NOISE EMISSION LEVELS (IN dB)

	Intercity Buses	Transit Buses	School Buses	Light Vehicles	Medium Trucks	Heavy Trucks	Unmodified Motorcycles	Modified Motorcycles
Acceleration								
0-20 mph	81.6	81.0	77.6	63.3	75.1	82.7	72.3	87.5
0-30 "	82.0	81.0	78.1	65.1	75.6	82.8	73.9	89.1
0-40 "	82.3	81.1	78.4	66.5	76.2	83.0	74.4	89.6
0-50 "	82.6	81.2	78.9	68.2	76.8	83.4	74.7	89.9
0-60 "	82.8	81.5	79.4	69.9	77.7	84.0	74.9	90.1
Deceleration								
20-0 mph	68.1	63.7	63.7	53.4	65.8	73.9	61.5	75.7
30-0 "	71.4	67.8	67.8	59.0	70.0	77.3	65.9	80.1
40-0 "	73.8	70.6	70.6	63.0	73.0	79.6	69.0	83.2
50-0 "	75.6	72.9	72.9	66.1	75.1	81.4	71.4	85.6
60-0 "	77.1	74.7	74.7	68.7	76.8	82.7	73.4	87.6
Cruise								
<25 mph	76.0	73.0	73.0	62.7	77.2	83.6	66.9	81.1
24-34 "	76.0	73.0	73.0	65.3	77.2	83.4	71.3	85.5
35-44 "	78.4	75.8	75.8	69.3	78.1	84.2	74.4	88.6
45-54 "	80.2	78.1	78.1	72.4	80.2	85.7	76.9	91.1
>55 "	81.7	79.9	79.9	74.9	81.7	86.8	78.9	93.1
Idle	62.0	58.0	58.0	46.0	54.0	63.0	58.9	72.0

*Passenger cars and light trucks with four cylinder gasoline engine and manual transmission.

It can be seen from Table 5-5 that modified motorcycles are the noisiest vehicles under all conditions. As noise emission regulations for other vehicles take effect, the differences between modified motorcycles and other vehicles will increase further.

5.3 Noise Metrics

In this analysis, two methods are used to evaluate the health and welfare benefits of reduced motorcycle noise emissions. These methods estimate the general adverse response due to noise associated with the operation of motorcycles and the potential of everyday activity interference (sleep disturbances and speech interferences) attributable to individual motorcycle passbys.

Three noise metrics are principally used in these methods. The primary measures of noise exposure for general adverse response and annoyance are the Equivalent A-weighted Sound Level (L_{eq}) and the Day-Night Sound Level L_{dn}). Potential sleep disturbances are computed using the Sound Exposure Level (L_S) of the individual event as the primary measure of noise impact. Speech interference is calculated using the L_{eq} over the duration of the individual noise event. A brief description of these three noise metrics follows.

5.3.1 Equivalent Sound Level, L_{eq}

This analysis uses a noise measure that condenses the physical acoustic properties that are characteristic of a given noise environment into a simple indicator of the quality and quantity of noise. This general measure for environmental noise is the equivalent A-weighted sound level (L_{eq}) expressed in decibels (Reference 8). It correlates quite well with the overall long-term effects of environmental noise on public health and welfare.

The basic definition of L_{eq} is:

$$L_{eq} = 10 \log_{10} \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} 10 \frac{p^2(t)}{p_o^2} .dt \tag{3}$$

where (t_2 - t_1) is the interval of time over which the levels are evaluated, p (t) is the time-varying magnitude of the sound pressure, and p_o is a reference pressure standardized at 20 micropascals. When expressed in terms of A-weighted sound level, L_A, the equivalent A-weighted sound level, L_{eq}, is defined as:

$$L_{eq} = 10 \log_{10} \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} 10^{[L_A(t)/10]} .dt \tag{4}$$

When associated with a specific short-time interval, $(t_2 - t_1)$, or T, the L_{eq} (T) represents the energy-averaged sound level over that interval of time. Commonly used time intervals are 24-hour, 8-hour, 1-hour, day and night, symbolized as $L_{eq(24)}$, $L_{eq(8)}$, $L_{eq(1)}$, L_d and L_n, respectively.

5.3.2 Day-Night Sound Level, L_{dn}

In describing the impact of noise on people, a measure called the day-night sound level (L_{dn}) is used. This is a 24-hour measure with a weighting applied to nighttime noise levels to account for the increased sensitivity of people to noise intruding at night. The L_{dn} is defined as the equivalent noise level during a 24-hour period, with a 10 dB weighting applied to the equivalent noise level during the nighttime hours of 10 p.m. to 7 a.m. The basic definition of L_{dn} in terms of the A-weighted sound level is:

$$L_{dn} = 10 \log_{10} \left[\frac{1}{24} \left(\int_{0700}^{2200} 10^{L_A(t)/10} .dt + \int_{2200}^{0700} 10^{[L_A(t)+10]/10} .dt \right) \right] \quad (5)$$

When values for average or equivalent sound levels during the daytime or nighttime hours (L_d and L_n, respectively) are given, L_{dn} may be expressed as:

$$L_{dn} = 10 \log_{10} \left[\frac{1}{24} \left(15 \times 10^{L_d/10} + 9 \times 10^{(L_n + 10)/10} \right) \right] \quad (6)$$

where L_d is the "daytime" equivalent level obtained between 7 a.m. and 10 p.m., and L_n is the "nighttime" equivalent level obtained between 10 p.m. and 7 a.m.

5.3.3 Sound Exposure Level, L_s

Most of the criteria which relate noise exposure to adverse human impact deals with people's exposure to noise over time rather than to discrete noise events. Specification of the noise environment in terms of day-night sound level is adequate for pervasive, long-term type noises, such as general traffic noise or aircraft noise. However, such measures may not be fully descriptive of the impact of the noise from single, isolated occurrences, such as a motorcycle passing by. In this case, a single noise event may contribute an insignificant amount to the total environmental noise, yet be of significant adverse impact. Some effects of noise on people have been quantified in terms of sound level (such as L_{eq}) over a particular duration. Others have been quantified by a simple metric which measures total sound energy over the duration of the event, the Sound Exposure Level (L_s). The sound exposure level is the integral of the mean square weighted sound pressure received at a specified distance during a single occurrence of a noise-producing event. The sound exposure level is defined as:

$$L_s = 10 \log_{10} \int_0^T \frac{p^2(t)}{p_0^2} \, .dt \qquad (7)$$

where $p(t)$ is the A-weighted sound pressure at time t, p_0 is the reference pressure (20 micropascals), and T is the duration of the noise event. For a typical motorcycle passby, the approximation to the sound exposure level is:

$$L_s = L_{max} + 10 \log_{10} (T/2.4) \qquad (8)$$

where T is the time in seconds over which the sound is present (within 10 dB of the maximum level experienced during the passby), and L_{max} is the maximum A-weighted sound level of the event (a more detailed description of the time history approximation may be found in reference 31).

5.4 Fractional Impact Method: See Appendix M

5.5 Health and Welfare Criteria - General Adverse Response

To project the potential benefits of reducing the noise from motorcycles, it is necessary to describe statistically the noise-exposed population (on a national basis) both before and after implementation of the regulation. This statistical description characterizes the noise exposure distribution of the population by estimating the number of people exposed to different magnitudes of noise as defined by metrics such as day-night sound level. This is conceptually illustrated in Figure M-1 of Appendix M, which compares the estimated distribution of the noise exposed population before and after implementation of a hypothetical regulation. This type of approach provides a basis for evaluating the change in noise impact due to a given regulatory action.

It is also necessary to distinguish, in a quantitative manner, between the differing magnitudes of impact upon different individuals exposed to different values of L_{dn}. That is, the magnitude of human response to noise generally increases progressively from an identified "no response" threshold to some extreme maximum projected impact -- the greater the exposure, the more extreme the response. Hence, once the identified level is exceeded, the degree of human response associated with the noise will increase with increased noise exposure.

To assess the impact of traffic noise using the fractional impact procedure, one needs a relation between the changes in traffic noise and the responses of the people exposed to the noise. There exists some variability in human response measures due to a number of social and demographic factors. In the aggregate, however, for residential locations, the average response of groups of people is related quite well to cumulative noise exposure as expressed in a measure such as L_{dn}. For example, the different forms of response to noise such as hearing damage, speech or other activity interference, and annoyance were related to L_{eq} or L_{dn} in the EPA Levels Document

(Reference 8). For the purposes of this part of the study, criteria based on L_{dn} presented in the EPA Levels Document are used. Furthermore, it is assumed for this analysis that if the outdoor level of L_{dn} is less than or equal to 55 dB, which is identified in the EPA Levels Document as requisite to protect the public health and welfare, no adverse impact in terms of general annoyance and community response exists.

The community reaction data presented in Appendix D of the EPA Levels Document (Reference 8) show that the expected reaction to an identifiable source of intruding noise changes from "none" to "vigorous" when the day-night sound level increases from 5 dB below the level existing without the presence of the intruding noise to about 20 dB above the level before intrusion. For this reason, a level of 20 dB above L_{dn} = 55 dB is considered to result in a vigorous reaction by the people exposed. At this level (L_{dn} = 75 dB), the percentage of the population which is "highly annoyed" by noise would be approximately 40 percent of the total exposed population. The data in the EPA Levels Document suggest that for environmental noise levels which are intermediate between 0 and 20 dB above L_{dn} = 55 dB, the impact varies linearly. That is, a 5 dB increase (L_{dn} = 60 dB) constitutes a 25 percent impact, and 10 dB increase (L_{dn} = 65 dB) constitutes a 50 percent impact, with a 20 dB increase representing maximum impact.

For convenience of calculation, a function for weighting the magnitude of noise impact with respect to general adverse reaction (annoyance) has been used (Figure 5-5). This function, normalized to unity at L_{dn} = 75 dB (a point of maximum expected impact for most communities), may be expressed as representing percentages of impact in accordance with the following equation:

$$W(L_{dn}) = \begin{cases} 0.05\ (L_{dn} - C) & \text{for } L_{dn} \geq C \\ 0 & \text{for } L_{dn} < C \end{cases} \qquad (9)$$

where $W(L_{dn})$ is the weighting function for general adverse response, L_{dn} is the measured or calculated community noise level, and C is the identified threshold below which the public is not considered at risk (L_{dn} = 55 dB). Note that the weighting function for general adverse response can exceed unity at levels greater than L_{dn} = 75 dB.

A recent compilation (References 9 and 10) of 18 social surveys from 9 countries shows, in fact, that the response curve relating "percent highly annoyed" to the noise measured around respondents' homes is best represented by a curvilinear function. However, it has also been shown that the single linear function can be used with good accuracy in cases where day-night sound levels range between L_{dn} values of 55 dB to 80 dB (Figure 5-5).

By using the derived relationship between community noise exposure and general adverse response (Equation 9), the Level Weighted Population (LWP)*

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* The procedures for deriving LWP were developed by the Committee on Hearing, Bioacoustics and Biomechanics of the National Academy of Sciences. Other terms such as Equivalent Population (Peq) and Equivalent Noise Impact (ENI) have been used interchangeably with LWP.

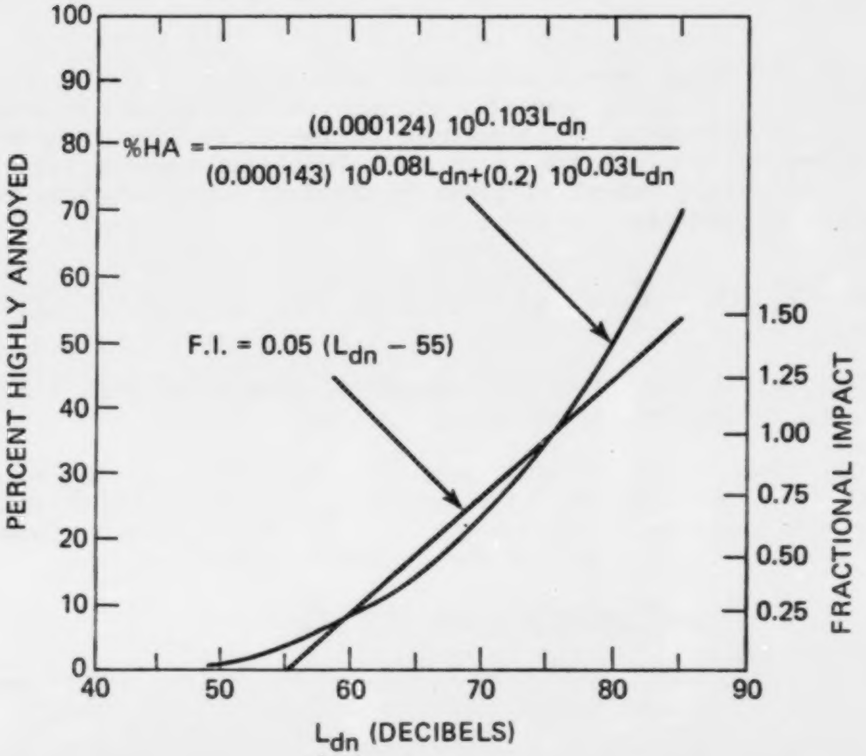

FIGURE 5-5 COMPARISON OF CURVILINEAR FUNCTION AND FRACTIONAL IMPACT LINEAR FUNCTION

associated with a given level of traffic noise (L^i_{dn}) may be obtained (Reference 9). The procedure involves multiplying the number of people exposed to that level of traffic noise by the relative weighting associated with this level as follows:

$$LWP_i = W(L^i_{dn}) \times P_i \qquad (10)$$

where LWP_i is the magnitude of the impact on the population exposed to traffic noise L^i_{dn} and is numerically equal to the number of people who would all have a fractional impact equal to unity (100 percent impacted). $W(L^i_{dn})$ is the weighting associated with an equivalent traffic noise level of L^i_{dn} (from equation 9), and P_i is the population exposed to that level of traffic noise. To illustrate this concept, if there are 1000 people living in an area where the noise level exceeds the criterion level by 5 dB (and thus are considered to be 25 percent impacted, $W(L_{dn}) = 0.25$), the environmental noise impact for this group is the same as the impact on 250 people who are 100 percent impacted (1000 x 25% = 250 x 100%). A conceptual example is portrayed in Figure 5-6.

When the total impact associated with traffic noise is assessed, the observed levels of noise generally decrease as the distance between the source and receiver increases. The magnitude of the total impact may be computed by determining the partial impact at each level and summing over each of the levels. The total impact is given in terms of Level Weighted Population by the following formula:

$$LWP = \sum_i LWP_i = \sum_i [W(L^i_{dn}) \times P_i] \qquad (11)$$

where $W(L^i_{dn})$ is the fractional weighting associated with L^i_{dn}, and P_i is the population exposed at each L^i_{dn}.

The change in impact associated with regulations on the noise emissions from traffic vehicles may be assessed by comparing the magnitude of the impacts with and without regulations in terms of the Relative Change in Impact (RCI), which is calculated from the following expression:

$$RCI = 100 \times \frac{[LWP\ (before) - LWP\ (after)]}{LWP\ (before)} \qquad (12)$$

This basic fractional impact procedure is also used to compute noise impact employing a variety of additional criteria (e.g., activity interference, hearing damage risk, etc.) other than general adverse response (Reference 11).

As discussed previously, the concept of fractional impact, expressed in units of LWP, is most useful for describing relative changes in impact from a specified baseline for the purpose of comparing benefits of alternative

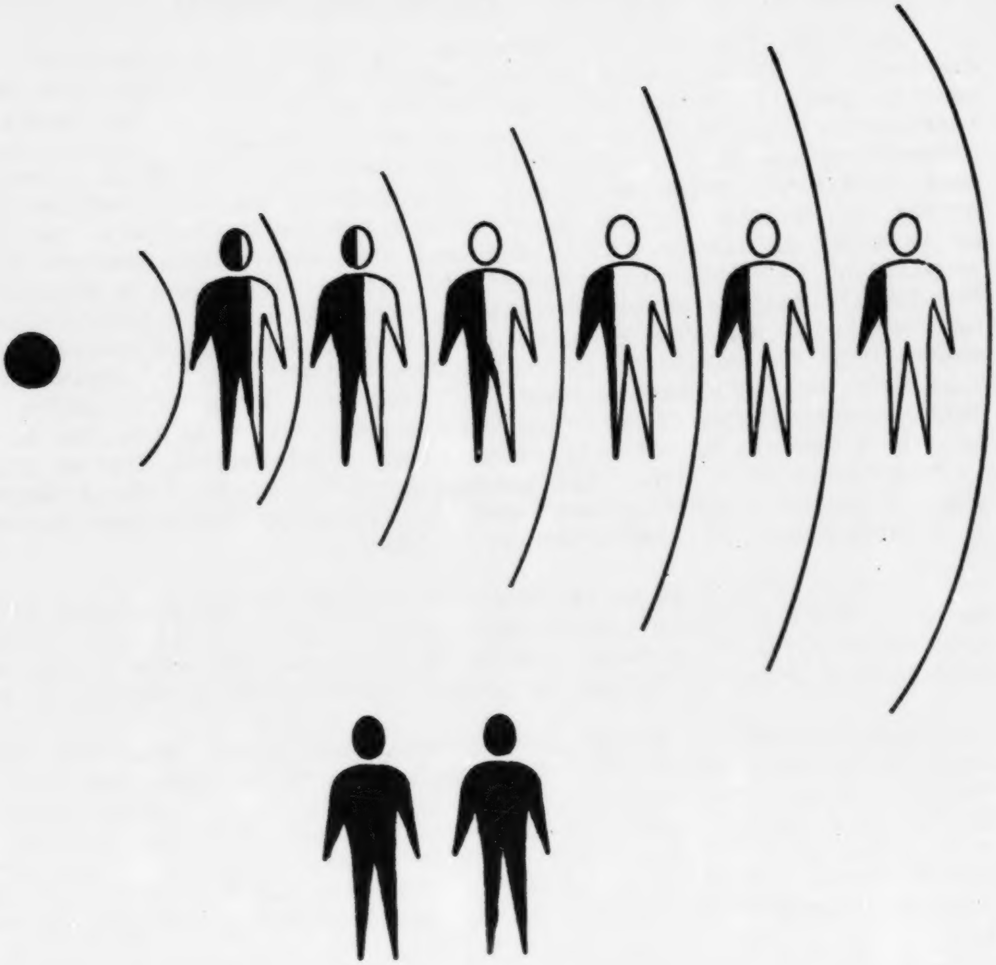

FIGURE 5-6. EXAMPLE OF FRACTIONAL IMPACT METHODOLOGY

The computation of LWP allows one to combine the number of people jeopardized by noise above an L_{dn} of 55 dB with the degree of impact at different noise levels. The circle is a source which emits noise to a populated area. The various partial amounts of shading represent various degrees of partial impact by the noise. The partial impacts are summed to give the LWP. In this example, six people who are adversely affected by the noise (partially shaded) results in a level weighted population (LWP) of two (totally shaded).

regulatory schedules. In order to assess the absolute impact or benefits corresponding to any regulatory schedule, one must have information on the distribution of population as a function of noise environment. The derivation of this type of information is discussed in Section 5.7.

5.6 Health and Welfare Criteria - Single Event Response

When the benefits of lessening the noise from motorcycles are being examined, it is important to look beyond the contribution that motorcycles make to overall average day-night traffic noise (L_{dn}). The impact contributions which are calculated in terms of average community response are somewhat generalized and do not necessarily represent specific impact situations. On some occasions, noise associated with motorcycles will combine with other noises, as described by the General Adverse Response analysis. At other times or in other situations, one can expect that other noise sources will not be significant, and thus each motorcycle passby will cause a distinct impact. The actual impact from motorcycles is certainly due to a combination of various levels of motorcycle noise and other environmental noise. Thus, the methodology for assessing general adverse response (as discussed in Section 5.5) will not take into account the fact that almost the entire amount of daily acoustical energy contributed by motorcycles in an area may be generated by only a few minutes of noise during many accelerations near an intersection in the course of a day. Yet these intrusive, short, intense events may be some of the most annoying noise-related situations faced over the entire day by a large number of pedestrians or residents.

It is difficult to derive a direct measure of the annoyance attributable to the intrusiveness of motorcycle noise. Numerous surveys indicate that motorcycle noise is a major source of annoyance but only a few scientific studies have directly related motorcycle sound levels to degrees of annoyance.

When queried in attitudinal surveys, respondents generally rate motorcycle noise as a major, if not the major, source of annoyance from traffic-related noise. For example, the response to noise survey questionnaires mailed to a random sample of individuals showed that the respondents rated motorcycles as the major noise "problem", while automobiles and trucks were ranked second and third as noise problems with rankings of 67 percent and 62 percent respectively, relative to motorcycle noise at 100 percent (Reference 12).

In another survey, respondents were asked to rate 25 noise sources on a scale from "not bothering at all" to "extremely bothering." Motorcycles were rated as "not bothering at all" by the smallest percentage of people and were rated as "extremely bothering" by the highest percentage of people. A total of 44.8 percent rated motorcycle noise as either "moderately," "highly," or "extremely" bothering in their neighborhoods (Reference 13). In the same study, people rated traffic noise situations in terms of both intensity and frequency of annoyance. People annoyed by motorcycle noise rated the intensity midway between "definitely annoying" and "strongly annoying." The only vehicle type receiving a higher annoyance intensity rating was buses. In terms of frequency, motorcycles were reported as the source of annoyance 23 percent of the time, second only to automobiles with a 36 percent frequency of annoyance. People are annoyed, it seems, by motorcycle noise greatly out of proportion to actual numbers of motorcycles, as compared to other types of traffic vehicles.

In one very applicable investigation, a sample of 57 persons rated vehicular noise at an open-air test track as the vehicles were driven by at a distance of 7.5 meters at the closest point (Reference 14). Listeners were exposed to both constant speed cruises and accelerations. Figure 5-7 shows the results of the subjective noise ratings of motorcycles as a function of A-weighted noise level as heard by the listener. Ratings ranged from "quiet" at 68.5 dB to "excessively noisy" at 96.5 dB. These results seem to compare fairly well with those of another study in which ratings of single noise events varied from "quiet" at 73 dB to "noisy (strongly)" at 92 dB (Reference 15).

A loud, short-duration vehicle passby may also interrupt people's activities, such as conversation, sleeping, TV viewing, reading etc. In a study of the annoyance caused by different levels of simulated aircraft noise for people seated indoors watching television, annoyance was found to be dependent, at least in part, on speech interference (Reference 16). Not only is the TV program, or other person speaking, more difficult to hear during the time in which a noisy event is taking place, but it has been observed that the distraction which may occur from the conversation in which the person is engaged may contribute in itself to annoyance (References 16 and 17). The speaker may attempt to cope with the noise intrusion behaviorally, either by increasing his or her vocal effort, or in more severe cases, by discontinuing conversation altogether. Such behavioral reactions may be indicative of general annoyance and disturbance with the intrusive noise event.

In general, interruptions of people's activities lead to annoyance (References 18 and 19), and represent a degradation of health and welfare. For example, the reaction to a noise intrusion during sleep is, in many cases, a change in sleep stage (from a "deeper" to a "lighter" stage) or, if the intrusive noise is intense or of prolonged duration, an actual awakening may result. In either case, repeated disturbance of people's sleep can be expected to adversely affect health and well-being.

Several investigations have shown that expressed annoyance with noise correlates well with interference of activities due to noise (References 8, 20, 21, 22, 23, 24, and 25). One survey found that reports of interferences with sleep and speech communication correlate more highly with feelings of generalized annoyance than with any other factor, including actual sound levels measured outdoors (Reference 18).

For these reasons, the analysis of vehicle passby impacts were examined in some detail to assess the significance of potential individual event exposures upon human activities (References 26 and 27), in particular, the activities of speech communication and sleep. The analysis was undertaken to determine both the direct effect motorcycle noise may have on these activities, and to estimate the total potential annoyance attributable to motorcycle noise. These single event pass-by noise intrusions become particularly important in light of other regulations and efforts to reduce the noise from other motor vehicles and urban noise sources. Namely, without a reduction in noise emissions for motorcycles, the motorcycle will stand out as one of the most, if not the most, intrusive noise sources.

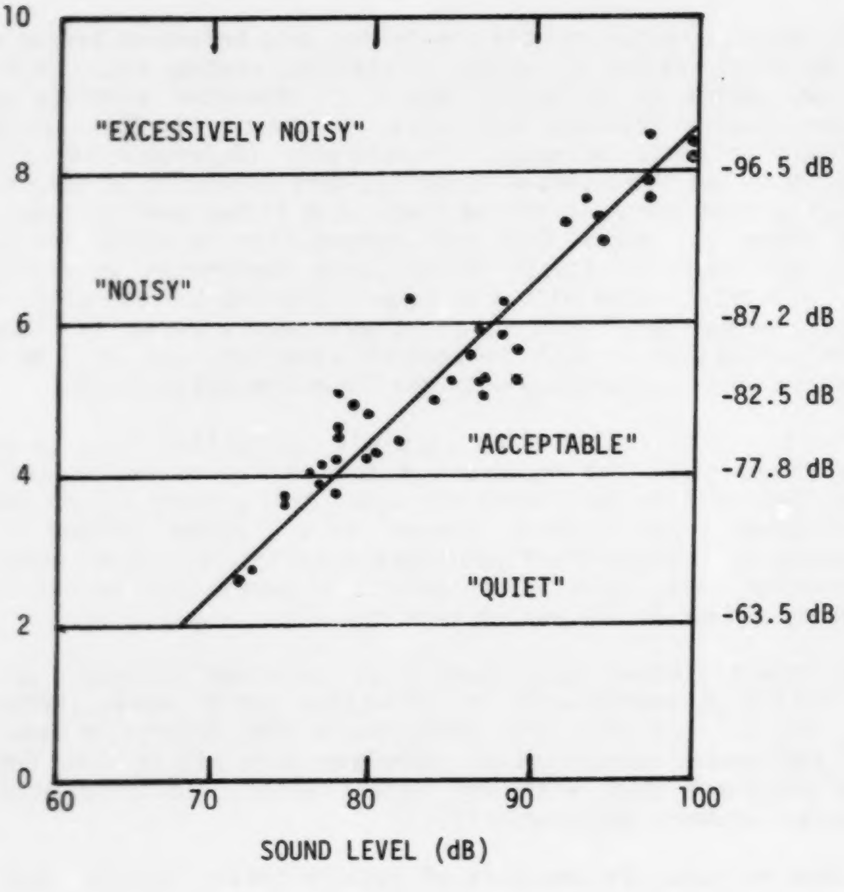

FIGURE 5-7. SUBJECTIVE NOISE RATING OF MOTORCYCLE SOUND LEVELS

source: reference 14

5.6.1 Sleep Disturbance

The sleep periods of humans are typically classified into five stages. In Stages I and II, sleep is light and the sleeper is easily awakened. Stages III and IV are states of deep sleep where a person is not as easily awakened by a given noise, but the sleep may shift to a lighter stage. An additional stage, termed rapid eye movement (REM), corresponds to the dream state. When exposed to an intrusive noise, a sleeper may (1) show response by a brief change in brainwave pattern, without shifting sleep stages; (2) shift to a lighter sleep stage; or (3) awaken. The greatest known impact occurs due to awakening, but there are also indications that disruption of the sleep cycle can cause impact (irritability, etc.) even though the sleeper may not awaken (Reference 2).

A recent study (References 28 and 29) has summarized and analyzed sleep disturbance data as gathered under experimental laboratory conditions. This study demonstrated a relationship between frequency of response (disturbance or awakening) and noise level, and further demonstrated that the duration of the noise stimulus was a critical parameter in predicting response. The study also showed that the frequency of sleep disruption is predicted by noise exposure better than is arousal or behavioral awakening. An important fact is that sleep disturbance is defined as any physiological change which occurs as a result of a stimulus. The person undergoing such disturbance may be completely unaware of being afflicted; however, the disturbance may adversely affect total sleep quality. This effect on overall sleep quality may lead to, in certain situations, undesirable behavioral or physiological consequences (Reference 2).

Data relating to the anticipated disruption of sleep caused by noise is shown in Figure 5-8 (top). These data illustrate the frequency of sleep disturbance (as measured by changes in sleep state, including behavioral awakening) as a function of the sound exposure level (L_S) of the intruding noise. The frequency of behavioral awakening as a function of sound exposure level is also shown in Figure 5-8 (bottom). These relationships, adapted from Figures 1 and 2 of Reference 28, consist of data derived from a review of most of the recent experimental data on sleep and noise relationships. These relationships show the approximate degree of expected impact (percent disruption or awakening) at given levels of noise. For example, in Figure 5-8, an indoor sound exposure level of 60 dB would be expected to result in a 31 percent probability of a sleep disruption (change in depth of sleep). The probability of being awakened is less than that of being disturbed. For this example of a sound exposure level of 60 dB, the probability of being awakened is 17 percent (see Figure 5-8).

Note also that the noise data contained in the references cited were measured in terms of "effective perceived noise level" with a reference duration of 0.5 seconds, L_{EPN} (0.5 sec.). This level was converted to L_S by the following approximate relationship*:

$$L_S = L_{EPN}\ (0.5\ \text{sec.}) - 16\ \text{dB} \qquad (13)$$

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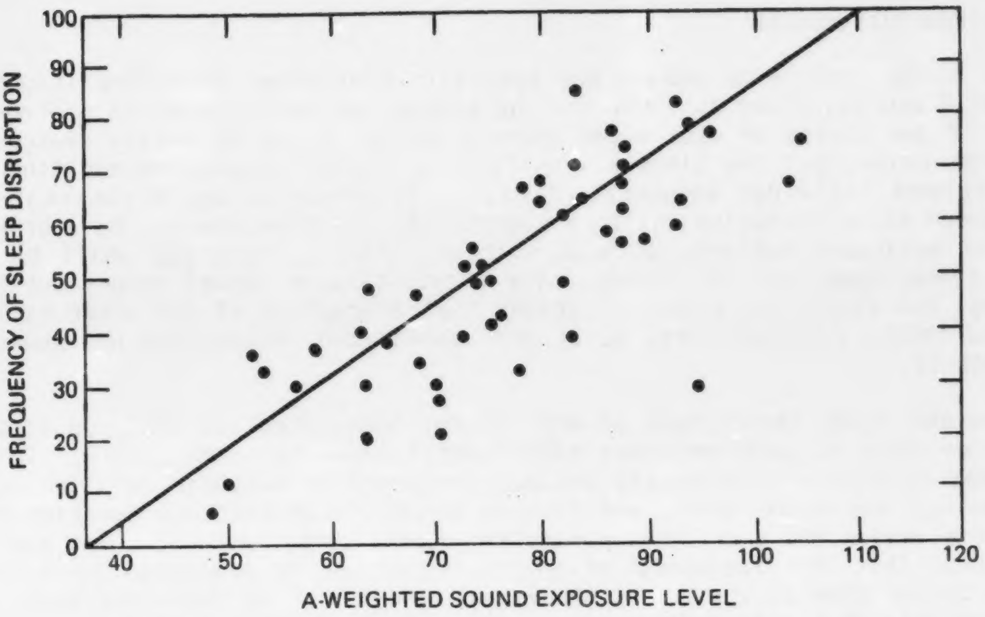
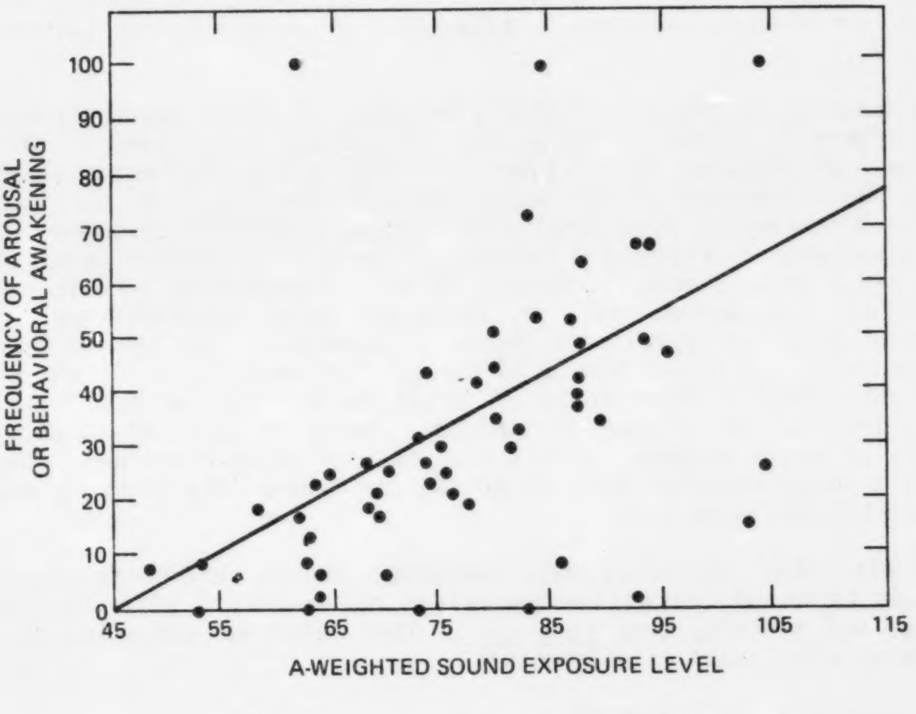
* This equation accounts for the average difference of 13 dB between Perceived Noise Level and A-weighted sound level, and the 3 dB that results from the change in reference time from 0.5 seconds, used in Reference 28, to 1 second, used in sound exposure level.



PROBABILITY OF A NOISE INDUCED SLEEP STAGE CHANGE



PROBABILITY OF A NOISE INDUCED AWAKENING

FIGURE 5-8 WEIGHTING FUNCTIONS FOR NOISE INDUCED SLEEP DISRUPTION AND SLEEP AWAKENING

adapted from reference 28

The impact weighting function scale for both disturbance and awakening is defined such that a probability of 100 percent disturbance or awakening has a Fractional Impact or weighting of 1.0, and a probability of zero percent has a weighting of zero. The Level Weighted Population for sleep disturbance and awakening was derived for each of the regulatory schedules and study years under investigation by using Equations 10 and 11, substituting $W(L_s)$ for $W(L_{dn})$. The impact weighting function for these two situations is calculated by using the following regression equations (from Figure 5-8):

$$W(L_s) = 0.0135\ (L_s - 37) \text{ for sleep disturbance, and} \tag{14}$$

$$W(L_s) = 0.0110\ (L_s - 45) \text{ for sleep awakening.} \tag{15}$$

5.6.2 Speech Interference

As is the case with sleep disruption, speech interference occurs as a result of individual noise events. The potential for speech interference (i.e., the interruption of conversation) due to motorcycle noise occurs when externally-propagating noise exceeds certain levels. However, unlike sleep disruption, the impact of noise on speech interference is not cumulative. That is, the duration of the noise event causing speech interference does not affect the kind of interference, although it does, of course, affect the duration of the interference. This is in contrast to sleep disturbance, where the cumulative effect of noise can change the impact from one of sleep disturbance to an actual sleep awakening. Therefore, the appropriate noise metric for measuring speech interference potential is an L_{eq} averaged over the duration of the event, rather than a sound exposure level which specifically considers the effect of the duration on the event.

Also, unlike sleep disruption, interference of speech may occur when people are either indoors or outdoors. The degree of speech interference from noise is dependent on the particular circumstances involved. Noise level and duration, separation distance of the conversers, and vocal effort are all factors that influence speech intelligibility (Reference 8). The criteria showing degrees of outdoor and indoor speech interference from noise are shown in Figures 5-9 and 5-10, respectively (Reference 8).

It should be recognized that the analysis does not assume that everyone is talking all the time. The procedure instead assesses a potential for speech interference and associated annoyance. Although the exact function of the population that is engaged in conversation or listening activities at any one instant is unknown, the actual relative benefits for speech interference should be the same as the potential relative benefits calculated in these analyses. Also, the relationships displayed in Figures 5-9 and 5-10 pertain to sentences known to listeners. All listeners are further assumed to have normal hearing. Under everyday environmental conditions, it would be expected that communication intelligibility would be somewhat less than that portrayed in Figures 5-9 and 5-10. For those people suffering some hearing loss, background noise levels need to be up to 10 dB lower to attain the same degree of intelligibility (Reference 30).

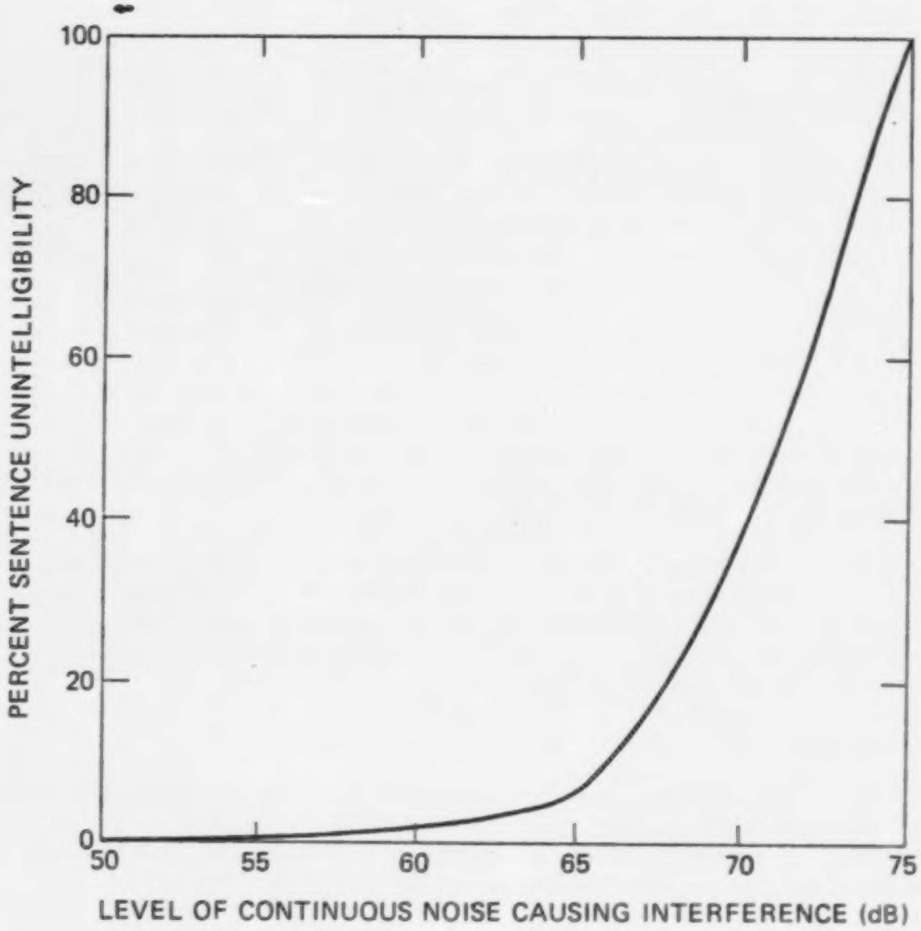


FIGURE 5-9 WEIGHTING FUNCTION FOR INDOOR SPEECH INTERFERENCE (RELAXED CONVERSATION AT GREATER THAN 1 METER SEPARATION, 45 dB BACKGROUND IN THE ABSENCE OF INTERFERING NOISE)

FROM REFERENCE 8

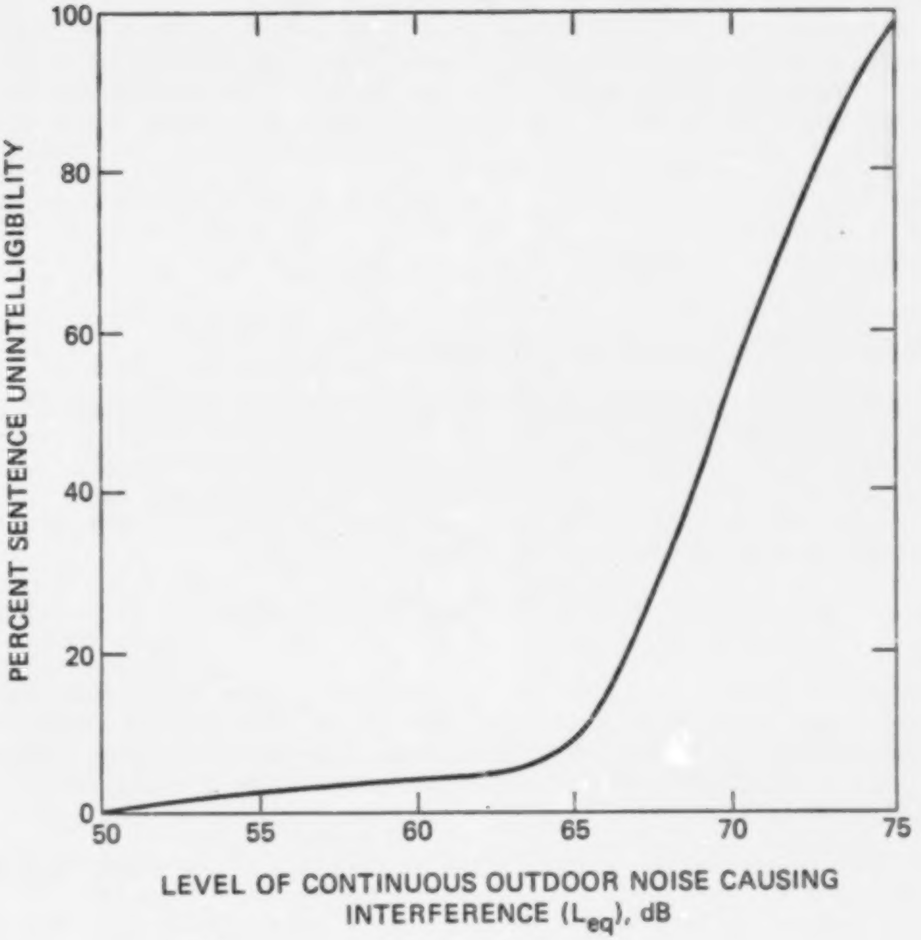


FIGURE 5-10 WEIGHTING FUNCTION FOR OUTDOOR SPEECH INTERFERENCE (NORMAL VOICE AT 2 METERS)

FROM REFERENCE 8

People can have their conversations disrupted by externally propagated motorcycle noise in at least three major settings during the day: as pedestrians on the street, as residents inside their homes, or as residents who are involved in activities just outside their homes. Three different approaches are required to assess the impact of these three different situations. Each approach will be examined separately. In the discussions that follow, "inside the home" and "outside the home" should be taken to mean, respectively, "inside any building" and "outside any building, but not along the street."

5.6.2.1 Indoor Speech Interference

Indoor speech interference is assumed to occur when motorcycle noise propagates through walls of residences or buildings and peaks above a typical indoor background level of 45 dB. The criteria of impact for indoor speech interference is given in Figure 5-9. The curve is based on the reduction of sentence intelligibility (sentences known to listeners) relative to the intelligibility which would occur at 45 dB. For people conversing indoors during the time of a vehicle passby, Figure 5-9 shows the probability of a disruption in communication. The appropriate metric in Figure 5-9 is the equivalent sound level over the duration of the event. The Level Weighted Population for indoor speech interference is obtained by using equations 10 and 11, substituting $W(L_{eq(T)})$ for $W(L_{dn})$, and letting P_i represent the number of people exposed at each indoor sound level for each passby.

5.6.2.2 Outdoor Speech Interference

The population exposed to potential outdoor speech communication interference are those people who are outside of their homes but not along a street. This analysis does not take into account pedestrians or people engaged in other forms of transportation during the day. Rather, it is intended to include those time-periods in which people are relaxing or engaged in other activities outdoors.

Outdoor speech interference due to the operation of motorcycles occurs when the maximum noise level of the pass-by exceeds an outdoor background level of 50 dB. For this analysis, 55 dB is used as the average outdoor background level. Although the outdoor background noise level in a number of urban areas may today be greater than 55 dB, coordinated Federal, state, and local efforts to reduce urban noise make the 55 dB level an appropriate value to use on a national basis for future years (the primary focus of this predictive analysis).

The criterion for outdoor speech interference is shown in Figure 5-10 as a function of the level of an interfering noise. Note that the appropriate noise metric against which percent speech interference (unintelligibility of sentences known to listeners) is plotted is an equivalent sound level over the duration of the pass-by. The Level Weighted Population for outdoor speech interference may be computed by using Figure 5-10 and equations 10 and 11.

5.6.2.3 Pedestrian Speech Interference

Speech communication may be especially difficult for pedestrians who are nearby roadway traffic. This is because pedestrians are typically located very close to the vehicles as they travel by. Pedestrian speech interference is calculated by considering a percentage of the population to be pedestrians located at the edge of clear zones associated with each roadway. Figure 5-10 and equations 10 and 11 are then used to evaluate the speech interference impact upon pedestrians.

Again, it should be noted that the single event noise analysis examines the effects of motorcycle noise alone, and hence does not take into account the presence of other noise sources in the environment. It is obvious that other environmental noise sources create background noise at such levels in certain situations that motorcycle noise may be masked. This analysis only represents the benefits accrued during those times when motorcycle noise clearly intrudes over the ambient or background noise level. The overall absolute impact upon activities is, of course, dependent on the background level assumed. However, the calculated benefits are representative of the relative reduction in community impact of motorcycle noise over any given ambient noise level.

5.7 Noise Prediction Model

The prediction model used in this health and welfare analysis is titled, "The National Roadway Traffic Noise Exposure Model." This predictive model is a more sophisticated version of the original health and welfare model presented in the "Proposed Motorcycle Noise Emission Regulation: Background Document". The National Roadway Traffic Noise Exposure Model was recently developed under EPA sponsorship, for the purpose of more accurately estimating nationwide traffic noise impact. Its documentation is contained in a single volume report (Reference 31) available from the Office of Noise Abatement and Control, U.S. Environmental Protection Agency. Reference 31 explains the methodology used by the computer model. The specific data contained in Reference 31 does not necessarily represent the updated data gathered for the motorcycle study (see Appendix N). The computer program itself is also available from EPA.

In this subsection we present an overview of the National Roadway Traffic Noise Exposure Model. Details of the model are presented in Appendix N, though not to the same detail as in the documentation report (Reference 31). Appendix N contains information on the data, the calculations, and the assumptions that underlie the model. Particular attention is given to those details critical to the analysis of motorcycle noise emission regulatory alternatives. The discussion in Appendix N covers defined inputs and basic assumptions that underlie the computer predictions.

5.7.1 General Overview of the Model

The model consists of two parts: the General Adverse Response part and the Single Event Response part. These two parts of the model appear side-by-side in Figure 5-11, to emphasize their similarity.

Both parts of the model start with user-defined input, keyed as $\boxed{U}$ in the figure. For example, such input includes the potential emission limits for newly manufactured motorcycles as they are typically operated. Both parts of the model then mathematically combine this user-defined input with large

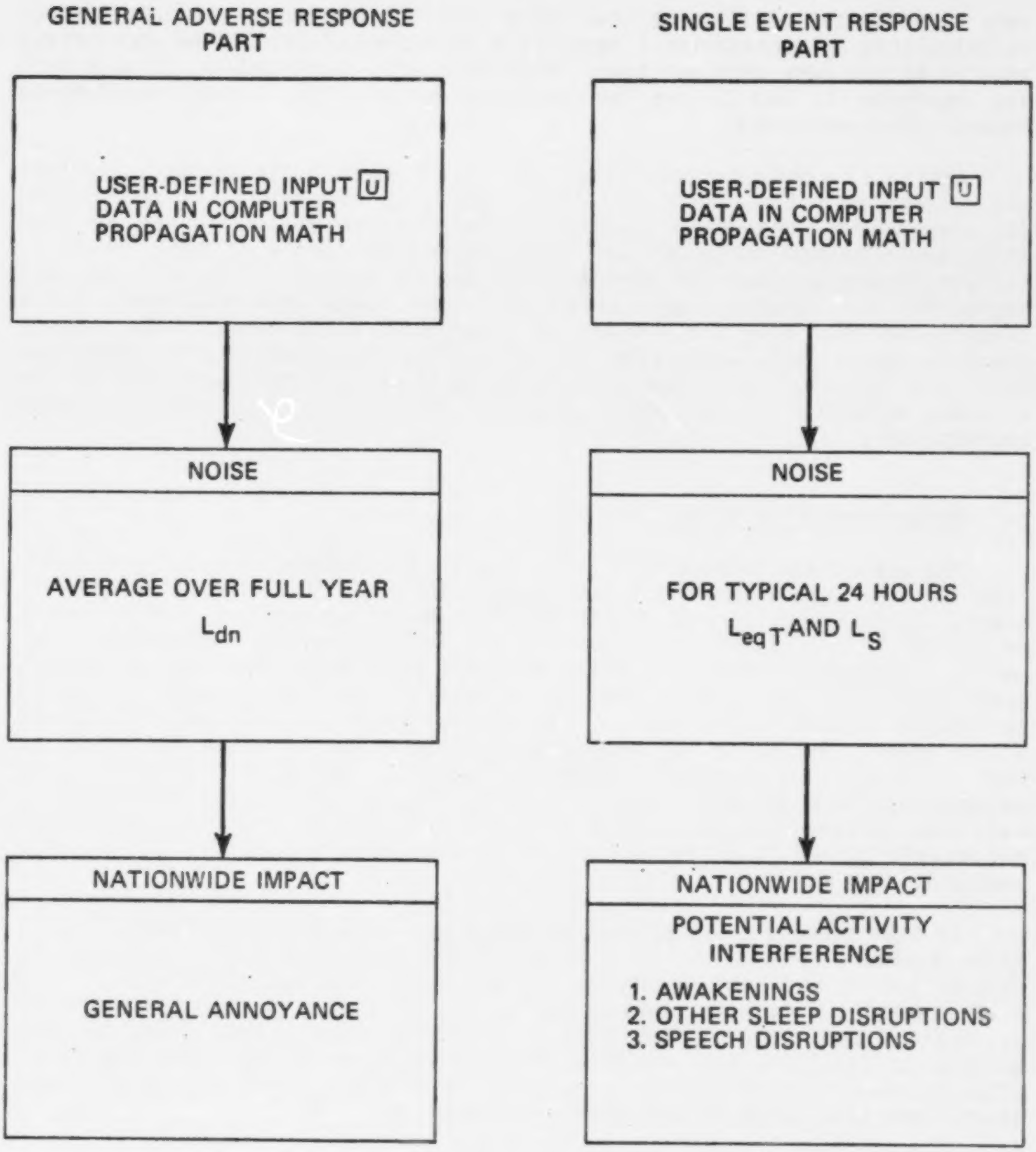

GENERAL ADVERSE RESPONSE PART
SINGLE EVENT RESPONSE PART
USER-DEFINED INPUT U DATA IN COMPUTER PROPAGATION MATH
USER-DEFINED INPUT U DATA IN COMPUTER PROPAGATION MATH
NOISE
AVERAGE OVER FULL YEAR
L dn
NOISE
FOR TYPICAL 24 HOURS
L eq T AND L S
NATIONWIDE IMPACT
GENERAL ANNOYANCE
NATIONWIDE IMPACT
POTENTIAL ACTIVITY INTERFERENCE
1. AWAKENINGS
2. OTHER SLEEP DISRUPTIONS
3. SPEECH DISRUPTIONS

FIGURE 5-11. THE NATIONAL ROADWAY TRAFFIC NOISE EXPOSURE MODEL

quantities of additional data that reside within the computer program. These additional data include noise emissions of other vehicles, as well as traffic data, roadway configuration data, noise propagation data, and residential population data.*

Both parts of the model then combine these data to predict the particular noise levels of interest. The General Adverse Response part predicts the day-night noise level, L_{dn}, averaged over a full year. In a parallel manner, the Single Event Response part predicts both Sound Exposure Level, L_s and the single-event Equivalent Sound Level, $L_{eq(T)}$, for each vehicle passby on a typical day during the year.

As discussed previously, the yearly-average noise level correlates well with noise-induced annoyance in and around the home -- that is, with a person's general adverse response. On the other hand, the noise from individual vehicles, not averaged into the ambient noise background due to other sources, often predicts additional impact due to particularly noisy or isolated single events. These three noise descriptors -- L_{dn}, L_s, and $L_{eq(T)}$ -- were discussed in detail Section 5.3.

As shown in the last module in Figure 5-11, the model converts the computed noise levels into measures of estimated impact. The General Adverse Response part of the model estimates the extent to which people in the United States will be highly annoyed by traffic noise experienced at or near their homes. The Single Event part estimates the potential of a single noise source (in this case motorcycles) to awaken people from sleep, to otherwise disrupt their sleep, and to interfere with people's speech at home, both indoors and outdoors.

In summary, the flow in Figure 5-11 progresses from user-defined input, through the data and mathematics within the computer program, to the predicted noise levels -- and then estimates potential noise impacts. The two parts of the model estimate two different aspects of noise impact: yearly-average and single-event. Both aspects are estimated nationwide.

5.7.2 Overview of the Noise Exposure Predictions: General Adverse Response

Figure 5-12 illustrates the manner in which noise predictions are made for the National Roadway Traffic Noise Exposure Model, for General Adverse Response. The figure is keyed ① through ③ to coordinate with the detailed discussions that follow.

This predicative procedure is best explained by starting with key ③ which addresses the predicted noise exposure for Person #1. As shown in Figure 5-12, noise exposures are also predicted for Person #2, Person #3, etc. In essence, the model statistically predicts the noise for every person in the United States -- a 1974 total population of 216.7 million persons, and rising.

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* The remainder of the discussion will not generally distinguish between user defined input and input data that resides within the program. See Reference 31 for further details.

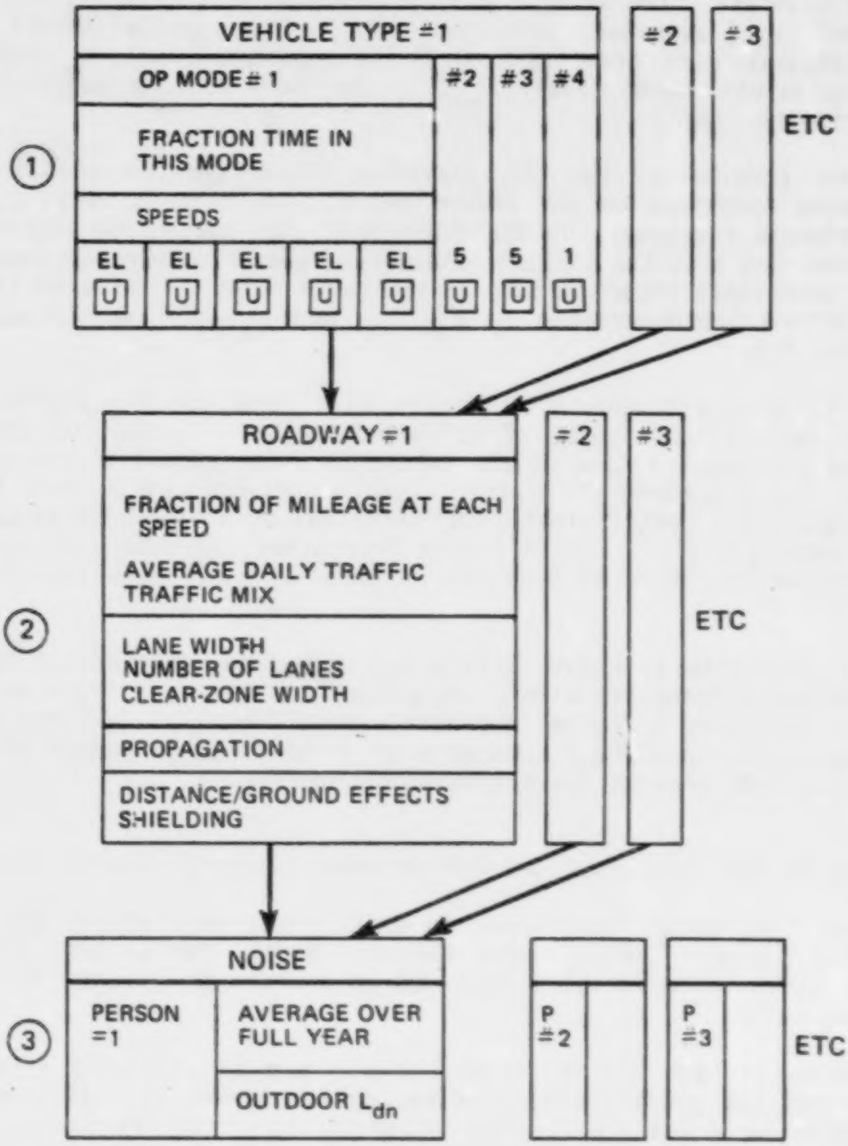

VEHICLE TYPE #1
#2
#3
OP MODE# 1
#2
#3
#4
FRACTION TIME IN THIS MODE
SPEEDS
EL
EL
EL
EL
EL
5
5
1
U
ETC
①
ROADWAY #1
#2
#3
FRACTION OF MILEAGE AT EACH SPEED
AVERAGE DAILY TRAFFIC
TRAFFIC MIX
LANE WIDTH
NUMBER OF LANES
CLEAR-ZONE WIDTH
PROPAGATION
DISTANCE/GROUND EFFECTS
SHIELDING
ETC
②
NOISE
PERSON #1
AVERAGE OVER FULL YEAR
OUTDOOR L_{dn}
P #2
P #3
ETC
③

FIGURE 5-12. NOISE EXPOSURE PREDICTIONS: GENERAL ADVERSE RESPONSE

* EL is the noise emission level. Each of the 5 speed ranges has a specific EL associated within. Idle mode has only one EL.

Rather than predicting the noise exposure of each individual, the computer groups people into homogeneous areas by city size and population density. Similar groupings occur throughout all blocks in Figure 5-12, though they are not indicated. The concepts involved in the prediction model are clearer without the details and approximations of grouping. These details and approximations are postponed for now.

In essence, then, the model statistically predicts the traffic noise environment experienced by everyone in the United States. The model also takes into account population growth for future years.

The noise level at Person #1 emanates from all the roadways within his hearing. (Key ② in Figure 5-12). Each roadway also has specified as input its average daily traffic and its average mix of vehicle types. Each roadway also has associated with it a large range of typical vehicle speeds. Although vehicle speeds vary on each roadway from moment to moment, the program considers their average speed for any given mile of roadway. The fractions of the total roadway mileage at each of five speed ranges are specific input used within the computer program, for each roadway.

In addition, each roadway has a specific lane width, a specific number of lanes, and a specific clear-zone width. The latter is generally the right-of-way width. It encloses the region within which no one lives.

Roadway noise, close by the roadway, is dependent upon vehicle speed, average daily traffic, traffic mix, lane width, number of lanes, and clear zone width. As this noise propagates outwards from the roadway to the person of interest, it is influenced by a number of propagation parameters. Two principal parameters are the distance between the person and the roadway, and the shielding that intervenes between the person and the roadway. These two parameters are specified for each person/roadway pair -- in groupings, as mentioned above.

From Key ③ to Key ② the noise level at each person's residence depends upon the source strength of each roadway, and upon the propagation of the noise from the roadway.

In addition to the above parameters, roadway source strength also depends, in part, on a number of other factors. As noted in Key ① each roadway contains a series of vehicle types. Each vehicle type operates in four modes, numbered in Figure 5-12. These modes are: acceleration, deceleration, cruise and idle. Each vehicle spends a definite fraction of its time in each of the four modes. These fractions are specified for each operating mode and separately for each vehicle type. Then each mode fraction is split into the five speed fractions specific to that roadway (Key ② again).

The final entries at Key ① are the noise emission levels. These differ for each of the four operating modes, and for each of the five speeds. These emission levels are a user-defined input, and are keyed therefore as U in the Figure. Specifically, the user defines the noise emission levels for new vehicle sales in any given year. Then the computer adds those vehicles to the ones already on the road, and depletes the general population of vehicles by those vehicles that retire from service.

The noise emission values put into the model constitute the mechanism by which we can investigate consequences (impacts) of a potential vehicle noise emission regulation. The model is applied for successive years, as more and more of the quieter vehicles are introduced into service. The year-to-year effect on predicted noise impact is a direct measure of the effectiveness of a regulation. (Figure 5-12 does not indicate this year-to-year application.)

In practice, then, Figure 5-12 flows from top to bottom. For the regulated vehicle type, emission levels corresponding to the regulatory levels are entered, separately for the four operating modes and separately for the five speed ranges within each operating mode (except idle). As shown in Figure 5-12, sixteen values of emission level are entered for each vehicle type.

These emissions are combined with the fractions of time spent by that vehicle type in each mode/speed, to obtain that vehicle's contribution to the traffic noise. The computer carries out these calculations for each vehicle type on that roadway. Then all vehicles are combined for Roadway #1, according to the average daily traffic and vehicle mix.

This process is repeated for each roadway type.

Each roadway's noise is then propagated to each person's residence. At each residence the noise levels from all roadways are combined into one total noise level.

This entire process is repeated for all persons in the United States (approximated by residential population density information), as shown to the right at Key ③ in Figure 5-12.

5.7.3 Overview of the Noise Exposure Predictions: Single Event Response

Figure 5-13 illustrates the noise prediction flow chart for the Single Event Response portion of the model. Differences between Figure 5-12 and Figure 5-13 are few, but important. Figure 5-13 examines only one vehicle type or class at a time, since only its passby noise is assessed.

Key ① data requirements are identical to the General Adverse Response portion of the model.

At Key ②, only the average daily traffic for that vehicle type is required, rather than the full traffic and vehicle mix. Also at Key ②, building noise isolation values are needed to propagate the noise from outdoors to indoors. These building noise isolation values are specified inputs.

The major differences between the Single Event and General Adverse Response portions of the model occur at Key ③. For each person, the single-event equivalent sound level, $L_{eq(T)}$, is computed for indoors, both day and night, and for outdoors, day only. These predictions then apply to the fraction of time the average person is at home day/night and indoors/outdoors. In addition, the sound exposure level, L_S, is computed for indoors, both day and night -- and then applied to the fraction of time that person is asleep, either day or night.

Key ③ summarizes the types of noise calculations made.

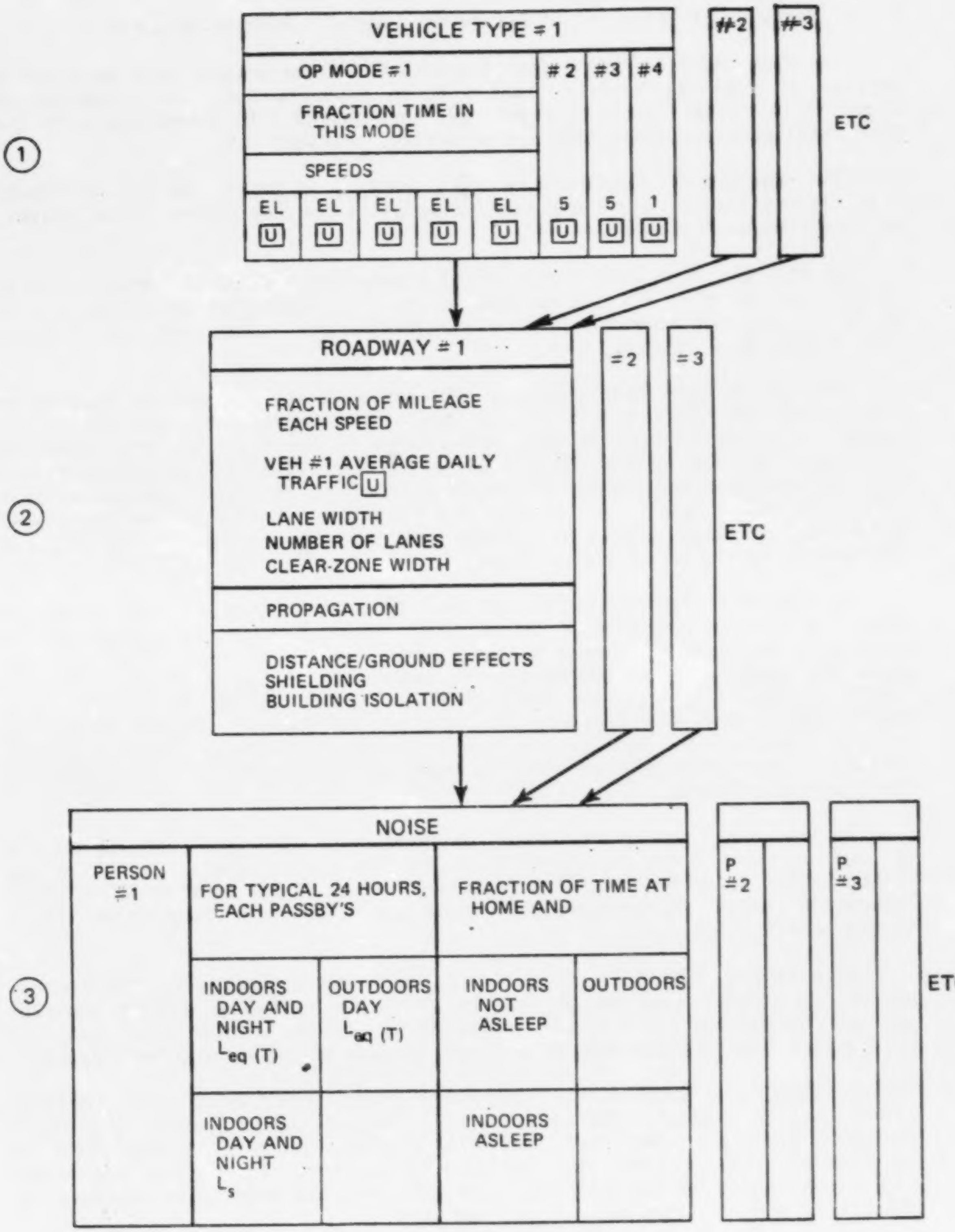

①
VEHICLE TYPE #1
OP MODE #1
#2
#3
#4
FRACTION TIME IN THIS MODE
SPEEDS
EL
EL
EL
EL
EL
5
5
1
U
#2
#3
ETC
②
ROADWAY #1
#2
#3
FRACTION OF MILEAGE EACH SPEED
VEH #1 AVERAGE DAILY TRAFFIC U
LANE WIDTH
NUMBER OF LANES
CLEAR-ZONE WIDTH
PROPAGATION
DISTANCE/GROUND EFFECTS
SHIELDING
BUILDING ISOLATION
ETC
③
NOISE
PERSON #1
FOR TYPICAL 24 HOURS, EACH PASSBY'S
FRACTION OF TIME AT HOME AND
INDOORS DAY AND NIGHT L_{eq} (T)
OUTDOORS DAY L_{eq} (T)
INDOORS NOT ASLEEP
OUTDOORS
INDOORS DAY AND NIGHT L_s
INDOORS ASLEEP
P #2
P #3
ETC

FIGURE 5-13. NOISE EXPOSURE PREDICTIONS: SINGLE EVENT RESPONSE

5.7.4 Overview of Noise Impact Estimates: General Adverse Response

The flow chart for noise impact estimates of the General Adverse Response portion of National Roadway Traffic Noise Exposure Model is presented in Figure 5-14. The Figure is keyed ③ through ⑥, to coordinate with the more detailed discussions that are presented in Appendix N.

The top set of modules, Key ③, duplicates the bottom set in Figure 5-12. It consists of all the person/noise pairs for the entire United States, as predicted by the model.

At Key ④, this very large set of person/noise pairs is sorted by noise level. For example, all the persons in the U.S. exposed to an outdoor L_{dn} of 55 dB are grouped together in this sorting process. The next set of boxes (top of Key ⑤) results.

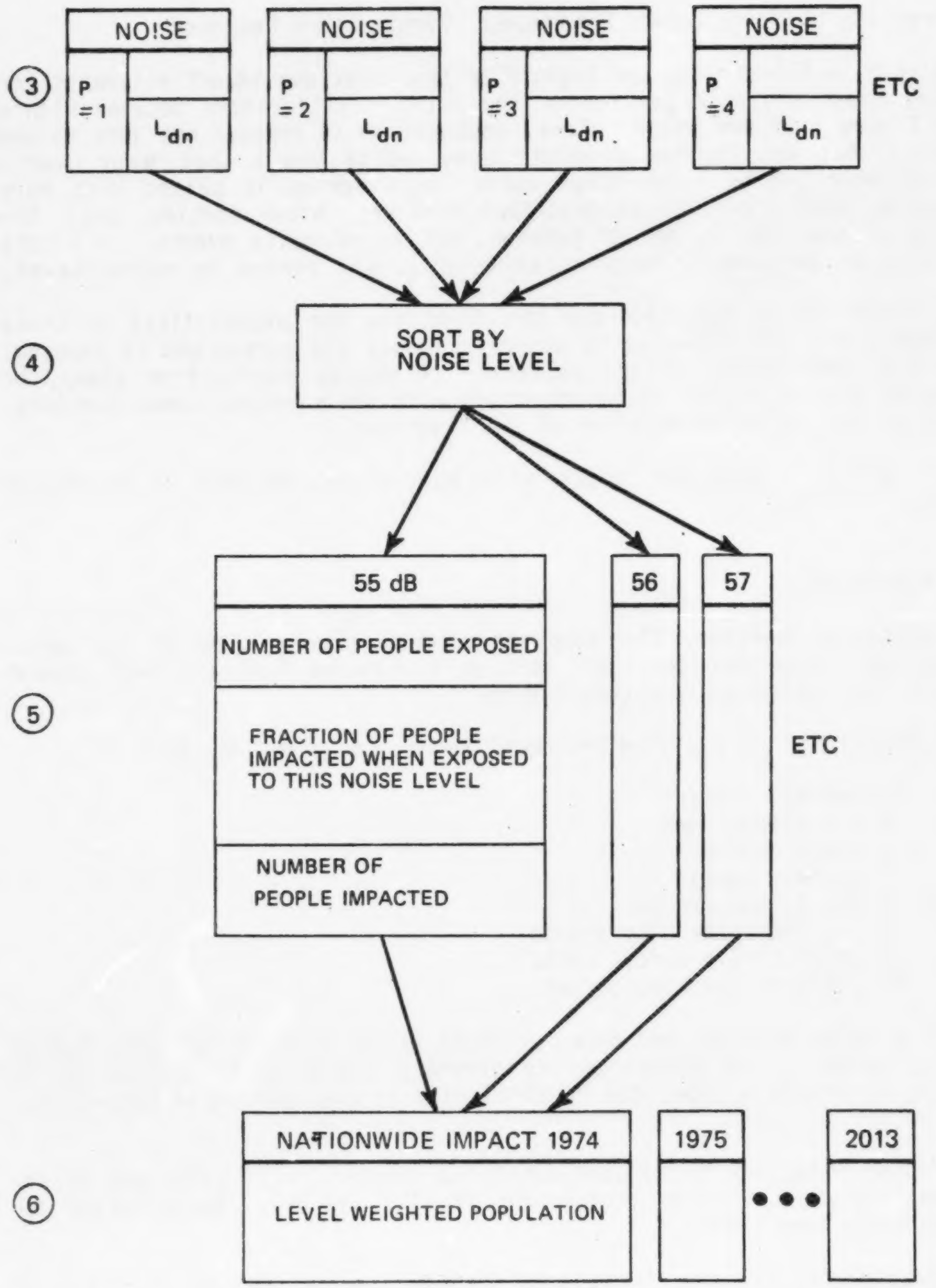
The top of each module in Key ⑤ contains all the persons exposed to that particular noise level. Noise impact is calculated by multiplying the number of people exposed at each noise level by the fractions next shown in the Figure (middle of Key ⑤). These are the fractional weighting values used to represent the number of people expected to be highly annoyed by that particular noise level. (See section 5.5 for an explanation of the fractional weighting values.) These fractions are essentially zero at 55 dB, and increase to nearly unity around 75 dB.

To complete the mathematics at Key ⑤, the number of people exposed times the appropriate fraction or weighting equals the Level Weighted Population (LWP) for General Adverse Response (equation 10) for each noise exposure band. For example, if 28,000 people are exposed to an L_{dn} of 60 dB, then this number of people, times the fraction 0.25, yields an LWP of 7,000. This number shows that not everyone is impacted to the same degree primarily because some may be less susceptible to noise intrusion. These fractions summarize, therefore, the variability among all persons in their reactions to the same noise level.

As the final step in the impact estimate (Key ⑥), the expected impacts at each exposure level are added to obtain the total expected impact in the United States (equation 11). The resulting number is the total Level Weighted Population (LWP). It combines population and noise level information into a single impact value.

Also at Key ⑥ in Figure 5-14 are the impact estimates for the remainder of the 40-year time stream. As an increasing number of quieter vehicles are introduced into service, the estimated impact should drop. The change in this impact from year-to-year is a direct measure of the regulation's benefit.

To rerun the program for subsequent years, additional noise emission values must be entered. The computer will then add these quieter vehicles to the ones already on the road, and will deplete the general population of vehicles by those vehicles that retire from service. These sales and depletion rates reside in the computer. In addition, the model also accounts for changes in United States population each year.



NOISE
P =1
Ldn
NOISE
P =2
Ldn
NOISE
P =3
Ldn
NOISE
P =4
Ldn
ETC
③
SORT BY NOISE LEVEL
④
55 dB
NUMBER OF PEOPLE EXPOSED
FRACTION OF PEOPLE IMPACTED WHEN EXPOSED TO THIS NOISE LEVEL
NUMBER OF PEOPLE IMPACTED
56
57
ETC
⑤
NATIONWIDE IMPACT 1974
LEVEL WEIGHTED POPULATION
1975
2013
⑥

FIGURE 5-14. NOISE IMPACT ESTIMATES: GENERAL ADVERSE RESPONSE

5.7.5 Overview of Noise Impact Estimates: Single Event Response

Figure 5-15 illustrates the logic flow that provides impact estimates for the Single Event Response portion of the model. Differences between Figure 5-14 and Figure 5-15 are minor. Here, each person is exposed not just to one noise level, but to a series of single-event noise levels that occur over a typical 24 hour period. In other words, each person is paired with many noise levels, each predicted as described earlier. After sorting, then, the tabulation of Key ⑤ is not of persons, but is of noise events. A single person will be exposed to many noise events, all sorted by noise level.

The fractions in Key ⑤ are the fractions (or probability) of these single events that are expected to actually impact the person who is exposed. The measures used represent the potential to awaken people from sleep, or otherwise to disrupt sleep, or to interfere with one's speech communications. (See Section 5.6 for an explanation of the fractions.)

Each of these distinct types of single-event impacts is estimated separately.

5.7.6 Data Groups

As mentioned earlier, the computer program groups much of its data. Such grouping occurs throughout all modules in Figures 5-12 and 5-13, though grouping is not indicated in either figure.

The grouping of data within the model appear in Table 5-6, for:

- 14 vehicle types
- 4 operating modes
- 5 speed ranges
- 6 roadway types
- 9 population groups
- 4 population/density groups
- 33 population/density "cells"
- 40 years of the time stream

Vehicle types were grouped based on those groups used for all EPA studies of roadway noise. The groupings are strongly suggested by similarity in noise emission within a type, due to similarity in engineering or operational characteristics.

Operating modes are based upon extensive vehicle noise tests and appropriate data reduction methods (References 32, 33, and 34). Speed ranges are based upon these same tests.

Roadway types are the functional categories defined by the Federal Highway Administration (Reference 35).

Population groups are based on the data base assembled by the Federal Highway Administration (References 35, 36, and 37), and were refined using 1970 census data (Reference 38). Population density groups were also based upon these same Federal Highway Administration and census publications.

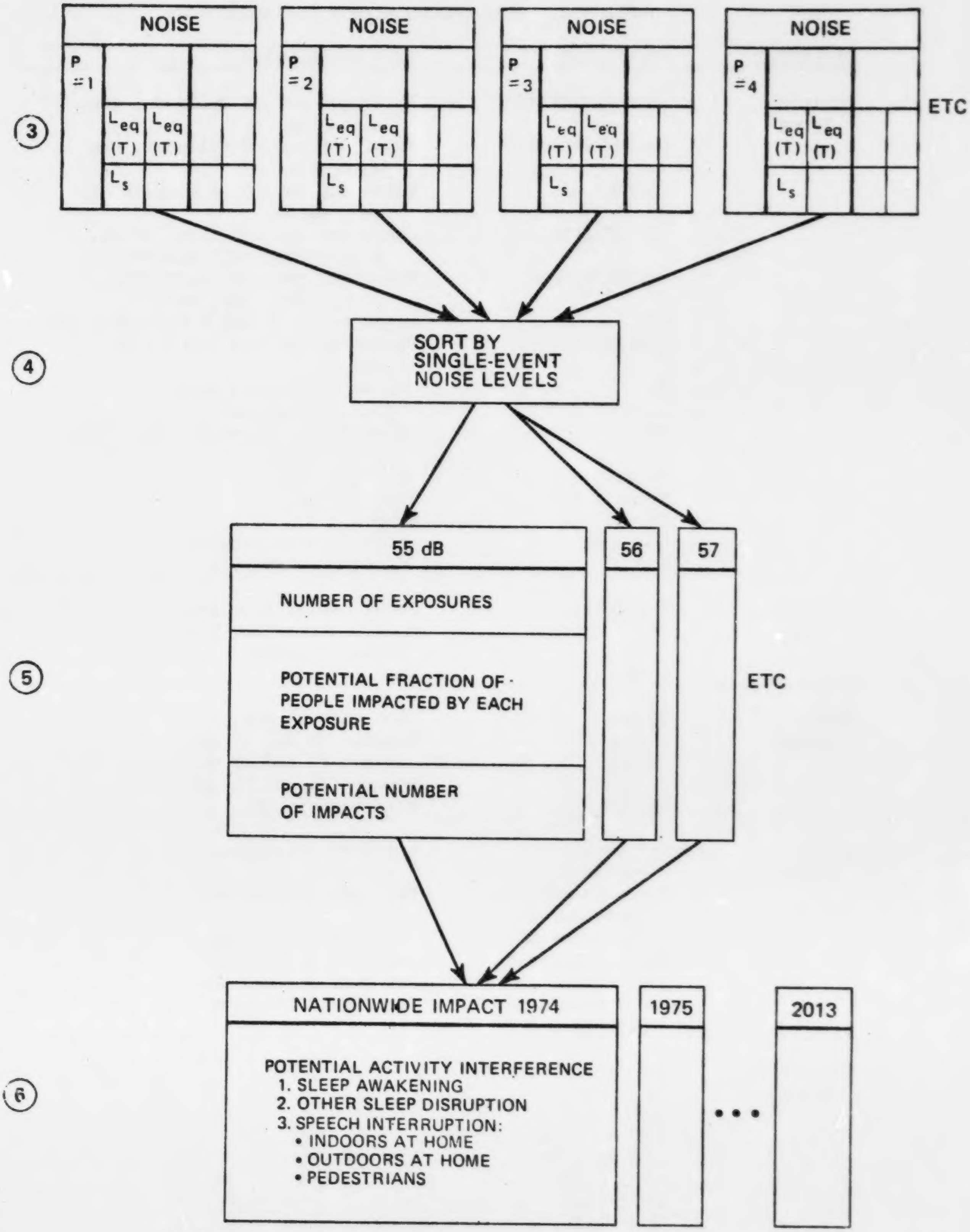

NOISE
P =1
L_{eq} (T)
L_{eq} (T)
L_s
NOISE
P =2
L_{eq} (T)
L_{eq} (T)
L_s
NOISE
P =3
L_{eq} (T)
L_{eq} (T)
L_s
NOISE
P =4
L_{eq} (T)
L_{eq} (T)
L_s
ETC
③
④
SORT BY SINGLE-EVENT NOISE LEVELS
⑤
55 dB
NUMBER OF EXPOSURES
POTENTIAL FRACTION OF PEOPLE IMPACTED BY EACH EXPOSURE
POTENTIAL NUMBER OF IMPACTS
56
57
ETC
⑥
NATIONWIDE IMPACT 1974
POTENTIAL ACTIVITY INTERFERENCE
1. SLEEP AWAKENING
2. OTHER SLEEP DISRUPTION
3. SPEECH INTERRUPTION:
• INDOORS AT HOME
• OUTDOORS AT HOME
• PEDESTRIANS
1975
• • •
2013

FIGURE 5-15. NOISE IMPACT ESTIMATES: SINGLE EVENT RESPONSE

TABLE 5-6. DATA GROUPS WITHIN THE MODEL

PARAMETER	GROUP NAME	TYPE DESCRIPTION
Vehicle Types	Car/8/automatic	Passenger car, 8 cylinder, gas, automatic
	Car/6/automatic	Passenger car, 6 cylinder, gas automatic
	Car/manual	Passenger car, 6 or 8 cylinder, gas, manual
	Car-LT/auto	Passenger car and light truck, 4 cylinder, gas, automatic
	Car-LT/manual	Passenger car and light truck, 4 cylinder, gas, manual
	LT	Light truck, 6 and 8 cylinder, gas
	Car-LT/diesel	Passenger car and light truck, diesel
	MT	Medium truck, two axle (GVWR 10,000 lb)
	HT	Heavy truck, three or more axles (GVWR 26,000 lb)
	Intercity bus	Intercity bus
	Transit bus	Transit bus
	School bus	School bus
	Unmod MC	Unmodified motorcycle
	Mod MC	Modified motorcycle
Operating Modes	Acceleration	Acceleration from zero to speed S
	Deceleration	Deceleration from speed S to zero
	Cruise	Cruise at speed S
	Idle	Idle
Speed Ranges	20 mph	Less than 25 mph
	30 mph	Between 25 and 35 mph
	40 mph	Between 35 and 45 mph
	50 mph	Between 45 and 55 mph
	60 mph	More than 55 mph
Roadway Types	Interstate Highways	Per FHWA definition
	Freeways and Expressways	Per FHWA definition
	Major Arterials	Per FHWA definition
	Minor Arterials	Per FHWA definition
	Collectors	Per FHWA definition
	Local Roads and Streets	Per FHWA definition
Population Groups	Population over 2M	
	1M to 2M	
	500K to 1M	
	200K to 500K	
	100K to 200K	
	50K to 100K	
	25K to 50K	
	5K to 25K	
	Rural areas	

Table 5-6. (continued)

PARAMETER	GROUP NAME	TYPE DESCRIPTION
Population Density Groups	1. High	More than 4,499 people per square mile
	2. Medium-to-High	3,000 to 4,499 people per square mile
	3. Low-to-Medium	1,500 to 2,999 people per square mile
	4. Low	Less than 1,500 people per square mile
Pop/density "cells"	1	Population over 2M, high density
	2	Same, medium-to-high density
	3	Same, low-to-medium density
	4	Same, low density
	5	1M to 2M, high density
	6	Same, medium-to-high density
	7	Same, low-to-medium density
	8	Same, low density
	9	500K to 1M, high density
	10	Same, medium-to-high density
	11	Same, low-to-medium density
	12	Same, low density
	...	
	29	5K to 25K, high density
	30	Same, medium-to-high density
	31	Same, low-to-medium density
	32	Same, low density
	33	Rural, low density only
Years	1974	For prediction of future impact
	1975	
	1976	
	1977	
	.	
	.	
	.	
	2013	

These two latter groups are then combined into pop/density "cells" shown next in Table 5-6. Thirty-three of these pop/density "cells" result, since the rural population group is paired with only the low-density group. These pop/density "cells" contain among them the entire U.S. population and also the entire U.S. roadway mileage. They therefore provide the structure for matching each person in the United States with the roadways that produce the noise at his residence.

Lastly, Table 5-6 shows that calculations are performed for all years within a 40-year time stream. A baseline year is selected.* For that year, all data (such as traffic counts, roadway mileage, population densities) are explicitly put into the computer program. Then for future years, these data are factored upward, if appropriate, to account for growth.

The data groups within Table 5-6 interrelate within the model in complex ways as discussed in the more detailed descriptions contained in Appendix N.

5.8 Results of Analysis - Street Motorcycles

As discussed in sections 5.5 and 5.6, results of the impact analysis for motorcycles center around two measures: (1) the Level Weighted Population, LWP, and (2) the Relative Change in Impact, RCI. LWP is an index which represents the total number of persons in the United States who are impacted by roadway noise during any given year of interest and the degree or severity of that impact upon each person. The RCI values represent the percentage change in LWP due to regulation relative to a baseline condition. A decrease in LWP results in a positive RCI -- that is, a benefit in terms of a percentage reduction in extent and severity of impact.

For this analysis RCI is calculated for each regulatory option using two different approaches. The first approach calculates the percentage change in LWP for a specific future year relative to the baseline condition in the year 1980. The results are tabulated as "RCI" (without an asterisk). Thus, RCI describes projected benefits relative to current day (1980) conditions. For example, an RCI of 25 percent in 1995 means that, in 1995, the adverse impact will be 25 percent less than it was in 1980 with no regulation in effect. Similarly, an RCI of negative 15 percent in 1995 means that the adverse impact has increased by 15 percent relative to 1980. These values of RCI include the effects of all changes between 1980 and the specified year in the future. That is, these RCI values reflect the impact of the motorcycle noise emission regulation and the influence of such factors as increased traffic volume, noise regulation of other vehicles, increases in the number of motorcycles and increases in the growth of the U.S. population.

The second approach calculates the percentage change in LWP for a specified future year relative to the same future year without a motorcycle regulation. These values of RCI are labeled as "RCI*" (with an asterisk). For a given year of interest, the RCI* values reflect the benefits attributable to the motorcycle noise regulation alone -- that is, benefits that will occur relative to that specific year if there were no motorcycle regulation. For example, an RCI* of 40 percent in 1995 is interpreted as a reduction in impact of 40 percent in 1995 from that which would occur in 1995 with no regulation. In brief,

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* For this analysis, much of the data was entered for 1974. These data were applied to later years after suitably adjusting for growth.

- RCI compares the impact in the year-of-interest (with regulation) to the impact in the year 1980, during which there is no regulation, less traffic, fewer motorcycle operations and a lower population.
- RCI* compares the impact in the year-of-interest (with regulation) to the same year, without regulation.

The RCI and RCI* values are considered to be more accurate predictors of actual benefits to be realized than the LWP values reported. This is because the RCI and the RCI* involve changes from a baseline condition. In the computation of RCI and RCI*, inaccuracies in baseline LWP tend to be cancelled out by the same inaccuracies in the year-of-interest LWP.

With these indices of noise impact -- LWP, RCI and RCI* -- two distinct types of impact are assessed: (1) General Adverse Response, based upon L_{dn}, and (2) Single Event Activity Interference, based upon L_S for sleep interference and upon $L_{eq(T)}$ for speech interference. In the discussions that follow, these two types of impact are addressed separately. For each, the results are tabulated for a series of future years (through the year 2010), and for a series of possible regulatory options (Table 5-1). Option Q represents the maximum benefits achievable and can be used as an upper limit guide.

5.8.1 General Adverse Response

The General Adverse Response portion of the model assesses the impact from the motorcycle noise emission regulation on a national aggregate basis. It does not assess the reduction in terms of specific localized street conditions which under some circumstances may show substantially greater relative benefits than indicated within this analysis.

The general adverse response impact estimates are presented in Tables 5-7 to 5-9. For each table, a different proportion of modified motorcycles (12, 7 and 3 percent) is considered (see Section 5.2.1.1). In each table the Level Weighted Population (LWP) and the Relative Change in Impact (RCI and RCI*) are shown for four years (1980, 1990, 2000, and 2010) in the regulatory time stream for motorcycles. In these tables, the baseline (no regulation) option is listed as Option 1. Also, the RCI and RCI* values in these tables are calculated relative to the condition of 12 percent modified motorcycles since this represents the current (1980) estimate of the proportion of modified motorcycles. Thus the impact and benefit estimates found in Tables 5-8 and 5-9 (with 7 and 3 percent modified motorcycles, respectively) represent changes in impact attributable to both lessened noise emissions and reduced number of modified vehicles. For example, in Table 5-8 (7 percent

TABLE 5-7

General Adverse Response Impact with 12 percent
Modified Motorcycles[1]

Regulatory Option	1981			1990			2000			2010		
	LWP^2	RCI^3	RCI*^{3}	LWP^2	RCI^3	RCI*^{3}	LWP^2	RCI^3	RCI*^{3}	LWP^2	RCI^3	RCI*^{3}
Option 1	29.4	0.00	0.00	31.6	-7.56	0.00	38.6	-31.47	0.00	47.5	-61.82	0.00
Option 2	-	-	-	31.4	-7.05	0.47	38.4	-30.79	0.52	47.3	-61.07	0.46
Option 3	-	-	-	31.1	-5.82	1.61	37.9	-28.99	1.89	46.7	-59.09	1.68
Option 4	-	-	-	31.1	-5.89	1.55	37.9	-28.99	1.89	46.7	-59.09	1.68
Option 5	-	-	-	30.9	-5.21	2.18	37.5	-27.79	2.80	46.3	-57.77	2.50
Option 6	-	-	-	31.0	-5.65	1.77	37.5	-27.79	2.80	46.3	-57.77	2.50
Option 7	-	-	-	30.9	-5.28	2.12	37.5	-27.79	2.80	46.3	-57.77	2.50
Option 8	-	-	-	31.0	-5.72	1.71	37.5	-27.79	2.80	46.3	-57.77	2.50
Option 9	-	-	-	30.9	-5.21	2.18	37.1	-26.43	3.83	45.9	-56.30	3.41
Option 10	-	-	-	31.0	-5.72	1.71	37.2	-26.74	3.60	45.9	-56.30	3.41
Option Q	-	-	-	30.4	-3.58	3.70	37.0	-26.02	4.15	45.8	-55.86	3.68

NOTES:

[1] In order to estimate the general adverse response impact of motorcycles in the traffic stream, the following assumptions were made regarding other vehicles:
(a) Light vehicles are unregulated
(b) Trucks are regulated as promulgated: 83 dB in 1978, 80 dB in 1982.
(c) Buses are regulated as follows: 83 dB in 1981, 80 dB in 1985, 77 dB in 1987.

[2] LWP = Level Weighted Population (millions)

[3] The relative changes in impact (RCI and RCI*) are with respect to Option 1, no motorcycle regulation, with 12 percent of the motorcycle population modified since this represents the current estimate of modified motorcycles.

TABLE 5-8

General Adverse Response Impact with 7 percent Modified Motorcycles[1]

Regulatory Option	1981			1990			2000			2010		
	LWP[2]	RCI[3]	RCI*[3]	LWP[2]	RCI[3]	RCI*[3]	LWP[2]	RCI[3]	RCI*[3]	LWP[2]	RCI[3]	RCI*[3]
Option 1	28.4[4]	3.30	3.30	29.9[4]	-1.70	5.45	36.3	-23.60	5.98	44.8	-52.49	5.77
Option 2	-	-	-	29.7	-1.19	5.92	36.1	-22.92	6.50	44.6	-51.74	6.23
Option 3	-	-	-	29.4	0.03	7.06	35.6	-21.08	7.90	44.0	-49.76	7.45
Option 4	-	-	-	29.4	-0.03	7.00	35.6	-21.08	7.90	44.0	-49.76	7.45
Option 5	-	-	-	29.2	0.51	7.50	35.3	-20.10	8.65	43.6	-48.64	8.15
Option 6	-	-	-	29.3	0.17	7.19	35.3	-20.10	8.65	43.6	-48.64	8.15
Option 7	-	-	-	29.2	0.44	7.44	35.3	-20.10	8.65	43.6	-48.64	8.15
Option 8	-	-	-	29.3	0.10	7.12	35.3	-20.10	8.65	43.6	-48.64	8.15
Option 9	-	-	-	29.2	0.51	7.50	35.0	-19.04	9.46	43.3	-47.51	8.84
Option 10	-	-	-	29.3	0.10	7.12	35.0	-19.28	9.27	43.3	-47.51	8.84
Option 9	-	-	-	28.8	1.87	8.77	34.8	-18.60	9.79	43.2	-47.04	9.13

NOTES:

[1] In order to estimate the general adverse response impact of motorcycles in the traffic stream, the following assumptions were made regarding other vehicles:
(a) Light vehicles are unregulated
(b) Trucks are regulated as promulgated: 83 dB in 1978, 80 dB in 1982.
(c) Buses are regulated as follows: 83 dB in 1981, 80 dB in 1985, 77 dB in 1987.

[2] LWP = Level Weighted Population (millions)

[3] The relative changes in impact (RCI and RCI*) are with respect to Option 1, no motorcycle regulation, with 12 percent of the motorcycle population modified since this represents the current estimate of modified motorcycles.

[4] These numbers are given to show the change in LWP due to a reduction in the number of modified motorcycles without concurrent reductions in the sound levels of new motorcycles.

TABLE 5-9

General Adverse Response Impact with 3 percent Modified Motorcycles[1]

Regulatory Option	1981			1990			2000			2010		
	LWP[2]	RCI[3]	RCI*[3]	LWP[2]	RCI[3]	RCI*[3]	LWP[2]	RCI[3]	RCI*[3]	LWP[2]	RCI[3]	RCI*[3]
Option 1	27.9[4]	4.97	4.97	28.9[4]	1.67	8.58	34.9[4]	-18.97	9.51	43.3[4]	-47.48	8.86
Option 2	-	-	-	28.7	2.18	9.06	34.7	-18.26	10.05	43.1	-46.70	9.35
Option 3	-	-	-	28.4	3.41	10.20	34.2	-16.42	11.45	42.5	-44.72	10.57
Option 4	-	-	-	28.4	3.34	10.13	34.2	-16.42	11.45	42.5	-44.72	10.57
Option 5	-	-	-	28.2	3.81	10.58	33.9	-15.60	12.07	42.2	-43.80	11.13
Option 6	-	-	-	28.3	3.51	10.29	33.9	-15.60	12.07	42.2	-43.80	11.13
Option 7	-	-	-	28.3	3.75	10.51	33.9	-15.60	12.07	42.2	-43.80	11.13
Option 8	-	-	-	28.4	3.44	10.23	33.9	-15.60	12.07	42.2	-43.80	11.13
Option 9	-	-	-	28.2	3.81	10.58	33.7	-14.82	12.67	42.0	-42.92	11.68
Option 10	-	-	-	28.4	3.44	10.23	33.8	-14.99	12.54	42.0	-42.92	11.68
Option Q	-	-	-	27.9	4.94	11.62	33.6	-14.34	13.03	41.8	-42.44	11.98

NOTES:

[1] In order to estimate the general adverse response impact of motorcycles in the traffic stream, the following assumptions were made regarding other vehicles:
(a) Light vehicles are unregulated
(b) Trucks are regulated as promulgated: 83 dB in 1978, 80 dB in 1982.
(c) Buses are regulated as follows: 83 dB in 1981, 80 dB in 1985, 77 dB in 1987.

[2] LWP = Level Weighted Population (millions)

[3] The relative changes in impact (RCI and RCI*) are with respect to Option 1, no motorcycle regulation, with 12 percent of the motorcycle population modified since this represents the current estimate of modified motorcycles.

[4] These numbers are given to show the change in LWP due to a reduction in the number of modified motorcycles without concurrent reductions in the sound levels of new motorcycles.

modified motorcycles), Option 5 in the year 2000 shows an RCI of -20.10 percent relative to 1980 with no regulation and 12 percent modified vehicles. Similarly, Option 5 in the year 2000 with 7 percent modified shows an RCI* of 8.65 percent relative to the year 2000 with no regulation and 12 percent modified vehicles.

It may first be noted from Tables 5-7 to 5-9 that the LWP increases and the RCI values become negative in future years even as more stringent regulations are imposed. This increase impact means that the projected benefits from reducing motorcycle noise emissions are expected to be overpowered by the anticipated increase in vehicular traffic as well as population growth in the United States between 1980 and the year 2010.

Also, Tables 5-7 to 5-9 shows that in terms of overall traffic noise impact, the regulation of motorcycles results in a moderate overall reduction in traffic noise impact due to the small motorcycle population and the dominance of trucks and automobiles in the overall traffic stream. It must be reemphasized that these estimates are for impact on nationwide aggregate basis. Such aggregate reductions on a national basis do not effectively point up the potentially significant benefits that would occur in the urban environment for situations where there is a high volume of motorcycles.

From Table 5-7 (with 12 percent modified motorcycles) it may be seen that benefits in terms of RCI* are predicted to range from one to four percent depending upon the regulatory option. The benefits shown in this table are those that would be experienced without a concurrent reduction in the number of modified motorcycles. With the exception of Option Q, Options 9 and 10 show the greatest benefits, and Options 1 and 2 the least. Options 5, 7 and 9 would demonstrate benefits earlier than the others. Tables 5-8 (7 percent modified) and 5-9 (3 percent modified) demonstrate similar trends with RCI* benefits reaching to over 9 and 12 percent, respectively. These benefits shown in Tables 5-8 and 5-9 are higher than those shown in Table 5-7 due to the reductions in the number of modified vehicles.

Benefits of reducing the number of modified motorcycles without concurrent noise reduction of newly manufactured motorcycles can be seen by comparing Option 1 (no regulation) across the tables. For example, reducing the proportion of modified motorcycles from 12 to 3 percent is found to yield an 8.86 percent benefit in the year 2010 in terms of reduction of overall traffic noise impact.

In Tables 5-7 to 5-9, the total United States impact is collapsed into a single-value LWP - for a given year and a given regulatory option. In this condensation, the numbers of persons exposed to different noise levels is lost. This population exposure information is presented in Tables 5-10 through 5-20. These tables show the number of persons in the United States who live in specific noise exposure areas, due to traffic noise, in 3-decibel ranges. Each table presents population exposure data for a separate regulatory option for 12, 7, and 3 percent modified motorcycles (see Section 5.2.1.1), with Option 1 again representing the case of no noise emission regulation. As an example to assist in interpretation of this table, under Option 1 (Table 5-10), in the year 2000 with 12 percent modified motorcycles, it is predicted that 128,670,000 people will be exposed to traffic noise at levels exceeding an L_{dn} of 55 dB, and 7,400,000 people will be exposed to levels greater than an L_{dn} of 70 dB. Likewise, under Option 7 (Table 6-16), in the year 2000 with an assumed 7 percent modified motorcycles, it is expected that 116,300,000 people would be exposed to traffic noise at an L_{dn} of 55 dB or above, and 6,900,000 people above an L_{dn} of 70 dB.

It may be noted that the trends of Tables 5-10 through 5-20 follow closely those of Tables 5-7 to 5-9. With the exception of idealized Option Q, Options 9 and 10 show the most benefits, with those of Option 9 occurring somewhat earlier. Options 1 and 2 show the least benefit. The tables also show that population exposure will increase over time despite the regulation of motorcycle noise emissions. This is due primarily to growth in the number of motorcycles and growth in the U. S. population. Again, substantial benefits are shown as the number of modified motorcycles is decreased from 12 to 3 percent.

5.8.2 Single Event Activity Interference

The purpose of the single event activity interference analysis is to examine the benefits of reducing motorcycle noise in greater detail. Here, potential activity interference is examined separately for (1) sleep disruption, (2) sleep awakening, and (3) speech interference, both indoors and outdoors, and pedestrian.

The single event impact estimates for motorcycles are presented for each regulatory option outlined in Table 5-1. Summary tables (organized identically to Tables 5-7 through 5-9 displayed previously) are presented for each of the single event impact measurements.

- Sleep Disruption (Tables 5-21 to 5-23)
- Sleep Awakening (Tables 5-24 to 5-26)
- Indoor Speech Interference (Tables 5-27 to 5-29)
- Outdoor Speech Interference (Tables 5-30 to 5-32)
- Pedestrian Speech Interference (Tables 5-33 to 5-35)

The tabulated results are presented in terms of LWP, RCI, and RCI* for four years (1980, 1990, 2000, and 2010) in the regulatory time stream. The results are also presented for the different assumptions of 12, 7 and 3 percent of the vehicles modified. In these tables, the baseline (no regulation) option is listed as Option 1. Also, the RCI and RCI* values are calculated relative to the condition of 12 percent modified motorcycles since this represents the current (1980) estimate of the proportion of modified motorcycles.

For sleep disruption, the Level Weighted Population (LWP) and both types of Relative Change in Impact (RCI and RCI*) appear in Tables 5-21 through 5-23. These tables show very large benefits in terms of a reduced potential

TABLE 5-10: POPULATION EXPOSED ABOVE L_{dn} = 55 dB - OPTION 1

	dB RANGE	91.- 88.	88.- 85.	85.- 82.	82.- 79.	79.- 76.	76.- 73.	73.- 70.	70.- 67.	67.- 64.	64.- 61.	61.- 58.	58.- 55.	TOTAL
% Modified	YEAR	MILLIONS OF PEOPLE												
12%	1981	0.00	0.00	0.00	0.20	0.58	1.54	3.43	6.53	11.19	16.28	23.68	31.50	94.94
	1990	0.00	0.00	0.01	0.20	0.60	1.52	3.39	6.65	11.55	18.02	27.65	37.23	106.83
	2000	0.00	0.00	0.03	0.30	0.81	2.02	4.24	8.10	13.85	21.67	33.84	43.81	128.67
	2010	0.00	0.00	0.07	0.45	1.13	2.72	5.51	10.08	16.77	26.07	40.71	50.04	153.58
7%	1981	0.00	0.00	0.00	0.19	0.57	1.51	3.36	6.43	10.98	15.80	22.20	29.36	90.39
	1990	0.00	0.00	0.00	0.19	0.58	1.46	3.27	6.41	11.12	17.01	25.33	34.24	99.61
	2000	0.00	0.00	0.03	0.29	0.78	1.93	4.07	7.76	13.26	20.16	30.73	40.84	119.85
	2010	0.00	0.00	0.08	0.43	1.09	2.62	5.30	9.71	16.08	24.09	37.05	47.27	143.73
3%	1981	0.00	0.00	0.00	0.19	0.56	1.48	3.31	6.33	10.82	15.59	21.69	28.64	88.61
	1990	0.00	0.00	0.00	0.18	0.56	1.41	3.17	6.21	10.80	16.52	24.26	32.93	96.04
	2000	0.00	0.00	0.03	0.27	0.76	1.86	3.93	7.49	12.84	19.42	29.31	29.27	115.17
	2101	0.00	0.00	0.07	0.42	1.06	2.54	5.13	9.42	15.66	23.24	35.48	46.00	139.02

TABLE 5-11: POPULATION EXPOSED ABOVE Ldn = 55 dB - OPTION 2

% Modified	dB RANGE YEAR	91.–88.	88.–85.	85.–82.	82.–79.	79.–76.	76.–73.	73.–70.	70.–67.	67.–64.	64.–61.	61.–58.	58.–55.	TOTAL
		MILLIONS OF PEOPLE												
12%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.01	0.20	0.60	1.51	3.37	6.63	11.50	17.94	27.49	37.08	106.33
	2000	0.00	0.00	0.03	0.30	0.81	2.01	4.22	8.05	13.79	21.55	33.64	43.65	128.06
	2010	0.00	0.00	0.09	0.45	1.12	2.71	5.49	10.04	16.71	25.94	40.50	49.92	152.95
7%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.00	0.19	0.58	1.45	3.25	6.38	11.07	16.93	25.18	34.05	99.08
	2000	0.00	0.00	0.03	0.29	0.78	1.92	4.05	7.72	13.20	20.05	30.52	40.61	119.16
	2010	0.00	0.00	0.08	0.43	1.08	2.61	5.28	9.67	16.01	23.97	36.82	47.08	143.03
3%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.00	0.18	0.56	1.40	3.15	6.18	10.75	16.45	24.10	32.73	95.50
	2000	0.00	0.00	0.02	0.27	0.75	1.85	3.91	7.44	12.77	19.31	29.08	39.02	114.43
	2101	0.00	0.00	0.07	0.42	1.05	2.53	5.10	9.37	15.59	23.11	35.23	45.79	138.28

TABLE 5-12: POPULATION EXPOSED ABOVE L_{dn} = 55 dB - OPTION 3

	dB RANGE	91.– 88.	88.– 85.	85.– 82.	82.– 79.	79.– 76.	76.– 73.	73.– 70.	70.– 67.	67.– 64.	64.– 61.	61.– 58.	58.– 55.	TOTAL
% Modified	YEAR	MILLIONS OF PEOPLE												
12%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.01	0.20	0.59	1.49	3.34	6.55	11.38	17.74	27.11	36.67	105.07
	2000	0.00	0.00	0.03	0.30	0.80	1.98	4.16	7.95	13.63	21.23	33.11	43.22	126.40
	2010	0.00	0.00	0.09	0.44	1.11	2.68	5.42	9.92	16.53	25.58	39.91	49.56	151.24
7%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.00	0.19	0.57	1.43	3.21	6.31	10.96	16.75	24.79	33.58	97.79
	2000	0.00	0.00	0.03	0.28	0.77	1.89	3.99	7.61	13.03	19.76	29.98	40.01	117.34
	2010	0.00	0.00	0.08	0.43	1.07	2.58	5.21	9.55	15.85	23.63	36.20	46.59	141.19
3%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.00	0.17	0.56	1.38	3.12	6.10	10.63	16.28	23.71	32.24	94.19
	2000	0.00	0.00	0.02	0.27	0.74	1.82	3.86	7.34	12.60	19.03	28.50	38.36	112.53
	2101	0.00	0.00	0.07	0.41	1.04	2.50	5.04	9.25	15.42	22.78	34.61	45.27	136.40

TABLE 5-13: POPULATION EXPOSED ABOVE L_{dn} = 55 dB - OPTION 4

	dB RANGE	91.- 88.	88.- 85.	85.- 82.	82.- 79.	79.- 76.	76.- 73.	73.- 70.	70.- 67.	67.- 64.	64.- 61.	61.- 58.	58.- 55.	TOTAL
% Modified	YEAR	MILLIONS OF PEOPLE												
12%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.01	0.20	0.59	1.49	3.34	6.56	11.39	17.75	27.13	36.69	105.15
	2000	0.00	0.00	0.03	0.30	0.80	1.98	4.16	7.95	13.63	21.23	33.11	43.22	126.40
	2010	0.00	0.00	0.09	0.44	1.11	2.68	5.42	9.92	16.53	25.58	39.91	49.56	151.24
7%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.00	0.19	0.57	1.43	3.21	6.31	10.97	16.76	24.81	33.61	97.87
	2000	0.00	0.00	0.03	0.28	0.77	1.89	3.99	7.61	13.03	19.76	29.98	40.01	117.34
	2010	0.00	0.00	0.08	0.43	1.07	2.58	5.21	9.55	15.85	23.63	36.20	46.59	141.19
3%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.00	0.17	0.56	1.38	3.12	6.11	10.64	16.29	23.73	32.27	94.27
	2000	0.00	0.00	0.02	0.27	0.74	1.82	3.86	7.34	12.60	19.03	28.50	38.36	112.53
	2101	0.00	0.00	0.07	0.41	1.04	2.50	5.04	9.25	15.42	22.78	34.61	45.27	136.40

TABLE 5-14: POPULATION EXPOSED ABOVE L_{dn} = 55 dB - OPTION 5

	dB RANGE	91.–88.	88.–85.	85.–82.	82.–79.	79.–76.	76.–73.	73.–70.	70.–67.	67.–64.	64.–61.	61.–58.	58.–55.	TOTAL
% Modified	YEAR	MILLIONS OF PEOPLE												
12%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.00	0.19	0.59	1.48	3.32	6.52	11.33	17.64	26.93	36.46	104.47
	2000	0.00	0.00	0.03	0.29	0.79	1.96	4.12	7.87	13.51	21.02	32.75	42.92	125.28
	2010	0.00	0.00	0.08	0.44	1.10	2.65	5.37	9.84	16.41	25.35	39.52	49.31	150.07
7%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.00	0.18	0.57	1.42	3.20	6.28	10.91	16.68	24.63	33.39	97.27
	2000	0.00	0.00	0.03	0.28	0.76	1.87	3.96	7.55	12.94	19.59	29.66	39.66	116.30
	2010	0.00	0.00	0.08	0.42	1.06	2.56	5.17	9.49	15.76	23.45	35.86	46.31	140.15
3%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.00	0.17	0.55	1.37	3.11	6.08	10.59	16.22	23.58	32.08	93.76
	2000	0.00	0.00	0.02	0.26	0.74	1.80	3.83	7.29	12.52	18.90	28.23	38.04	111.64
	2101	0.00	0.00	0.07	0.41	1.03	2.48	5.01	9.20	15.35	22.63	34.32	45.01	135.51

TABLE 5-15: POPULATION EXPOSED ABOVE L_{dn} = 55 dB - OPTION 6

	dB RANGE	91.– 88.	88.– 85.	85.– 82.	82.– 79.	79.– 76.	76.– 73.	73.– 70.	70.– 67.	67.– 64.	64.– 61.	61.– 58.	58.– 55.	TOTAL
% Modified	YEAR	MILLIONS OF PEOPLE												
12%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.01	0.20	0.59	1.49	3.33	6.54	11.37	17.71	27.06	36.61	104.91
	2000	0.00	0.00	0.03	0.29	0.79	1.96	4.12	7.87	13.51	21.02	32.75	42.92	125.28
	2010	0.00	0.00	0.08	0.44	1.10	2.65	5.37	9.84	16.41	25.35	39.52	49.31	150.07
7%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.00	0.18	0.57	1.43	3.21	6.30	10.95	16.73	24.75	33.53	97.65
	2000	0.00	0.00	0.03	0.28	0.76	1.87	3.96	7.55	12.94	19.60	29.66	39.66	116.30
	2010	0.00	0.00	0.08	0.42	1.06	2.56	5.17	9.49	15.76	23.45	35.86	46.31	140.15
3%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.00	0.17	0.56	1.38	3.11	6.10	10.62	16.26	23.67	32.20	94.07
	2000	0.00	0.00	0.02	0.26	0.74	1.80	3.83	7.29	12.52	18.90	28.23	38.04	111.65
	2101	0.00	0.00	0.07	0.41	1.03	2.48	5.01	9.20	15.35	22.63	34.32	45.01	135.51

TABLE 5-16: POPULATION EXPOSED ABOVE L_{dn} = 55 dB - OPTION 7

	dB RANGE	91.-88.	88.-85.	85.-82.	82.-79.	79.-76.	76.-73.	73.-70.	70.-67.	67.-64.	64.-61.	61.-58.	58.-55.	TOTAL
% Modified	YEAR	MILLIONS OF PEOPLE												
12%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.00	0.19	0.59	1.48	3.32	6.52	11.33	17.65	26.95	36.49	104.54
	2000	0.00	0.00	0.03	0.29	0.79	1.96	4.12	7.87	13.51	21.02	32.75	42.92	125.28
	2010	0.00	0.00	0.08	0.44	1.10	2.65	5.37	9.84	16.41	25.35	39.52	49.31	150.07
7%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.00	0.18	0.57	1.42	3.20	6.28	10.92	16.69	24.66	33.42	97.35
	2000	0.00	0.00	0.03	0.28	0.76	1.87	3.96	7.55	12.94	19.59	29.66	39.66	116.30
	2010	0.00	0.00	0.08	0.42	1.06	2.56	5.17	9.49	15.76	23.45	35.86	46.31	140.15
3%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.00	0.17	0.55	1.37	3.11	6.08	10.60	16.23	23.60	32.11	93.83
	2000	0.00	0.00	0.02	0.26	0.74	1.80	3.83	7.29	12.52	18.90	28.23	38.04	111.64
	2101	0.00	0.00	0.07	0.41	1.03	2.48	5.01	9.20	15.35	22.63	34.32	45.01	135.51

TABLE 5-17: POPULATION EXPOSED ABOVE L_{dn} = 55 dB - OPTION 8

	dB RANGE	91._ 88.	88._ 85.	85._ 82.	82._ 79.	79._ 76.	76._ 73.	73._ 70.	70._ 67.	67._ 64.	64._ 61.	61._ 58.	58._ 55.	TOTAL
% Modified	YEAR	MILLIONS OF PEOPLE												
12%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.01	0.20	0.59	1.49	3.33	6.55	11.38	17.72	27.08	36.64	104.98
	2000	0.00	0.00	0.03	0.29	0.79	1.96	4.12	7.87	13.51	21.02	32.75	42.92	125.28
	2010	0.00	0.00	0.08	0.44	1.10	2.65	5.37	9.84	16.41	25.35	39.52	49.31	150.07
7%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.00	0.18	0.57	1.43	3.21	6.30	10.95	16.74	24.77	33.55	97.72
	2000	0.00	0.00	0.03	0.28	0.76	1.87	3.96	7.55	12.94	19.60	29.66	39.66	116.31
	2010	0.00	0.00	0.08	0.42	1.06	2.56	5.17	9.49	15.76	23.45	35.86	46.31	140.15
3%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.00	0.17	0.56	1.38	3.12	6.10	10.63	16.27	27.30	32.23	94.15
	2000	0.00	0.00	0.02	0.26	0.74	1.80	3.83	7.29	12.52	18.90	28.23	38.04	111.65
	2101	0.00	0.00	0.07	0.41	1.03	2.48	5.01	9.20	15.35	22.63	34.32	45.01	135.51

TABLE 5-18: POPULATION EXPOSED ABOVE L_{dn} = 55 dB - OPTION 9

% Modified	dB RANGE / YEAR	91.-88.	88.-85.	85.-82.	82.-79.	79.-76.	76.-73.	73.-70.	70.-67.	67.-64.	64.-61.	61.-58.	58.-55.	TOTAL
		MILLIONS OF PEOPLE												
12%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.00	0.19	0.59	1.48	3.32	6.52	11.33	17.64	26.93	36.46	104.47
	2000	0.00	0.00	0.03	0.29	0.78	1.94	4.08	7.80	13.39	20.79	32.33	42.58	124.01
	2010	0.00	0.00	0.08	0.44	1.09	2.63	5.32	9.75	16.27	25.08	39.07	49.02	148.76
7%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.00	0.18	0.57	1.42	3.20	6.28	10.91	16.68	24.63	33.39	97.27
	2000	0.00	0.00	0.03	0.27	0.76	1.86	3.93	7.49	12.84	19.43	29.33	39.29	115.23
	2010	0.00	0.00	0.07	0.42	1.06	2.54	5.13	9.42	15.66	23.25	35.50	46.01	139.06
3%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.00	0.17	0.55	1.37	3.11	6.08	10.59	16.22	23.58	32.08	93.76
	2000	0.00	0.00	0.02	0.26	0.73	1.79	3.81	7.24	12.45	18.78	27.98	37.75	110.82
	2101	0.00	0.00	0.07	0.41	1.03	2.47	4.98	9.15	15.27	22.49	34.06	44.75	134.67

TABLE 5-19: POPULATION EXPOSED ABOVE L_{dn} = 55 dB - OPTION 10

	dB RANGE	91.- 88.	88.- 85.	85.- 82.	82.- 79.	79.- 76.	76.- 73.	73.- 70.	70.- 67.	67.- 64.	64.- 61.	61.- 58.	58.- 55.	TOTAL
% Modified	YEAR	MILLIONS OF PEOPLE												
12%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.01	0.20	0.59	1.49	3.33	6.55	11.38	17.72	27.08	36.46	104.47
	2000	0.00	0.00	0.03	0.29	0.79	1.94	4.09	7.81	13.41	20.85	32.43	42.66	124.30
	2010	0.00	0.00	0.08	0.44	1.09	2.63	5.32	9.75	16.27	25.08	39.07	49.02	148.76
7%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.00	0.18	0.57	1.43	3.21	6.30	10.95	16.74	24.77	33.55	97.72
	2000	0.00	0.00	0.03	0.28	0.76	1.86	3.94	7.51	12.86	19.47	29.41	39.37	115.47
	2010	0.00	0.00	0.07	0.42	1.06	2.54	5.13	9.42	15.66	23.25	35.50	46.01	139.06
3%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.00	0.17	0.55	1.38	3.12	6.10	10.63	16.27	23.70	32.23	94.15
	2000	0.00	0.00	0.02	0.26	0.73	1.80	3.81	7.25	12.47	18.81	28.04	37.82	111.01
	2101	0.00	0.00	0.07	0.41	1.03	2.47	4.98	9.15	15.27	22.49	34.06	44.75	134.67

TABLE 5-20: POPULATION EXPOSED ABOVE L_{dn} = 55 dB - OPTION Q

	dB RANGE	91.–88.	88.–85.	85.–82.	82.–79.	79.–76.	76.–73.	73.–70.	70.–67.	67.–64.	64.–61.	61.–58.	58.–55.	TOTAL
% MODIFIED	YEAR	MILLIONS OF PEOPLE												
12%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.00	0.19	0.58	1.46	3.27	6.42	11.17	17.37	26.44	35.90	102.81
	2000	0.00	0.00	0.03	0.29	0.78	1.93	4.07	7.77	13.35	20.72	32.20	42.47	123.62
	2010	0.00	0.00	0.08	0.43	1.09	2.62	5.31	9.73	16.23	25.00	38.94	48.93	148.36
7%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.00	0.18	0.56	1.40	3.16	6.20	10.78	16.49	24.02	32.85	95.82
	2000	0.00	0.00	0.02	0.27	0.75	1.85	3.92	7.46	12.80	19.36	29.19	39.13	114.77
	2010	0.00	0.00	0.07	0.42	1.05	2.53	5.12	9.39	15.62	23.17	35.35	45.89	138.62
3%	1981	-	-	-	-	-	-	-	-	-	-	-	-	-
	1990	0.00	0.00	0.00	0.17	0.55	1.36	3.07	6.01	10.48	16.05	23.21	31.61	92.51
	2000	0.00	0.00	0.02	0.26	0.73	1.79	3.79	7.22	12.41	18.71	27.84	37.58	110.34
	2101	0.00	0.00	0.07	0.41	1.02	2.46	4.96	9.12	15.23	22.42	33.91	44.59	134.19

for sleep disruption due to the regulation of motorcycle noise. These benefits represent reductions in that proportion of impact that is attributable to motorcycles alone.

The values of LWP contained in Tables 5-21 thru 5-23 are composite numbers representing the total number of people exposed to motorcycle passbys, multiplied by the number of motorcycle passby events to which they are exposed, weighted by the degree of anticipated interference. For example, if 32 million people are exposed nightly to motorcycle passby noise, and each is exposed to two separate passbys, and each passby has an independent probability of disrupting sleep of 40 percent, the total LWP displayed for that situation would be 25.6 million (32,000,000 X 2 X 0.40). Each cell in these tables represents such a composite number.

Again, the LWP values are indicators which are used to compare across regulatory options, and are not absolute measures of benefits. To better quantify the benefits of different regulatory options, the RCI and RCI* values are used.

From Tables 5-21 through 5-23, the results of the analysis for sleep disruption is summarized as follows:

- Assuming no reductions in the number of modified motorcycles (proportion of modified vehicles remains at the 12 percent level), the RCI becomes increasingly negative due primarily to increases in motorcycle operations and U.S. population growth. This trend is offset somewhat as increasingly stringent source emission regulations are imposed.
- With no motorcycle regulation (Option 1), the RCI becomes increasingly negative even with a concurrent reduction in the number of modified vehicles.
- The RCI values become increasingly positive as both the proportion of modified motorcycles is reduced and as increasingly more stringent source emission regulations are imposed.
- Options 9 and 10 demonstrate the greatest benefits in terms of RCI*. These benefits reach almost 50 percent in the year 2010 with no reduction in modified vehicles, and over 85 percent with an assumed three percent modified motorcycles. The idealized Option Q adds little additional benefit. Options 1 and 2 show the least benefit.
- In 1990, RCI* benefits range from zero to 50 percent with 12 percent modifications, and 40 to 85 percent with an assumed 3 percent modifications. The differences between options show the effects of regulatory lead time (effective dates) on near-term benefits.
- Benefits in terms of RCI* would reach in the year 2010 approximately 22 and 40 percent from reducing the proportion of modified vehicles to 7 and 3 percent, respectively, without a concurrent regulation on source emissions.
- In terms of RCI*, benefits would reach in the year 2010 between 40 and 50 percent for the most stringent regulatory alternatives even if the proportion of modified motorcycles were not at all reduced and remained at the 12 percent level.

TABLE 5-21

Sleep Disruption Impacts with 12 percent Modified Motorcycles

Regulatory Option	1980			1990			2000			2010		
	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]
Option 1	220.9	0.00	0.00	428.6	-94.02	0.00	599.0	-171.16	0.00	687.4	-211.18	0.00
Option 2	-	-	-	388.9	-76.05	9.26	542.7	-145.68	9.40	622.8	-181.94	9.40
Option 3	-	-	-	296.4	-34.18	30.84	402.9	-82.39	32.74	462.4	-109.33	32.73
Option 4	-	-	-	301.6	-36.53	29.63	402.9	-82.39	32.74	462.4	-109.33	32.73
Option 5	-	-	-	272.2	-23.22	36.68	351.9	-59.30	41.25	404.0	-82.89	41.23
Option 6	-	-	-	289.8	-31.19	32.38	352.1	-59.39	41.22	404.0	-82.89	41.23
Option 7	-	-	-	277.4	-25.58	35.28	351.9	-59.30	41.25	404.0	-82.89	41.23
Option 8	-	-	-	295.1	-33.59	31.15	352.1	-59.39	41.22	404.0	-82.89	41.23
Option 9	-	-	-	272.2	-23.22	36.49	316.3	-43.19	47.20	362.6	-64.15	47.25
Option 10	-	-	-	295.1	-33.59	31.15	324.5	-46.90	45.83	362.6	-64.15	47.25
Option Q	-	-	-	230.0	-4.12	46.34	315.5	-42.82	47.33	362.0	-63.88	47.34

NOTES:

[1] LWP = Level Weighted Population (millions)

[2] The relative changes in impact (RCI and RCI*) are with respect to Option 1, no motorcycle regulation, with 12 percent of motorcycle population modified since this represents the current estimate of modified motorcycles.

TABLE 5-22

Sleep Disruption Impacts with 7 percent Modified Motorcycles

Regulatory Option	1980			1990			2000			2010		
	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]
Option 1	172.3[3]	22.0	22.0	334.2[3]	-51.29	22.03	467.0[3]	-111.41	22.04	535.9[3]	-142.60	22.04
Option 2	-	-	-	292.6	-32.46	31.73	352.2	-59.44	41.20	468.1	-111.91	31.90
Option 3	-	-	-	196.3	11.14	54.20	262.7	-18.92	56.14	301.5	-36.49	56.14
Option 4	-	-	-	201.8	8.65	52.92	262.7	-18.92	56.14	301.5	-36.49	56.14
Option 5	-	-	-	174.2	21.14	59.36	215.8	2.31	63.97	247.7	-12.13	63.97
Option 6	-	-	-	190.3	13.85	55.60	216.0	2.22	63.94	247.7	-12.13	63.97
Option 7	-	-	-	179.5	18.74	58.12	215.8	2.31	63.97	247.7	-12.13	63.97
Option 8	-	-	-	195.8	11.36	54.32	216.0	2.22	63.94	247.7	-12.13	63.97
Option 9	-	-	-	174.2	21.14	59.36	188.3	14.76	68.56	215.7	2.35	68.62
Option 10	-	-	-	195.8	11.36	54.32	194.7	11.86	67.50	215.7	2.35	68.62
Option Q	-	-	-	138.1	37.48	67.78	187.5	15.12	68.70	215.1	2.63	68.71

NOTES:

[1] LWP = Level Weighted Population (millions)

[2] The relative changes in impact (RCI and RCI*) are with respect to Option 1, no motorcycle regulation, with 12 percent of the motorcycle population modified since this represents the current estimate of modified motorcycles.

[3] These numbers are given to show the effect of a reduction in the number of modified motorcycles without concurrent reductions in the sound levels of new motorcycles.

TABLE 5-23

Sleep Disruption Impacts with 3 percent Modified Motorcycles

Regulatory Option	1980			1990			2000			2010		
	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]
Option 1	132.1[3]	40.20	40.20	256.5[3]	-16.12	40.15	358.4[3]	-62.25	40.17	411.1[3]	-86.10	40.19
Option 2	-	-	-	213.2	3.49	50.26	297.2	-34.54	50.38	340.8	-54.28	50.42
Option 3	-	-	-	114.5	48.17	73.29	147.6	33.18	75.36	169.3	23.36	75.37
Option 4	-	-	-	120.0	45.68	72.00	147.6	33.18	75.36	169.3	23.36	75.37
Option 5	-	-	-	93.7	57.57	78.13	104.2	52.83	82.60	119.5	45.90	82.62
Option 6	-	-	-	108.9	50.70	74.59	104.3	52.78	82.59	119.5	45.90	82.62
Option 7	-	-	-	99.4	55.02	76.82	104.2	52.83	82.60	119.5	45.90	82.62
Option 8	-	-	-	114.5	48.17	73.29	104.3	52.83	82.59	119.5	45.90	82.62
Option 9	-	-	-	93.7	57.57	78.13	83.3	62.30	86.10	95.0	56.98	86.18
Option 10	-	-	-	114.5	48.17	73.29	88.1	60.12	85.29	95.0	56.98	86.18
Option Q	-	-	-	63.1	71.46	85.29	82.5	62.64	89.54	94.4	57.26	86.27

NOTES:

[1] LWP = Level Weighted Population (millions)

[2] The relative changes in impact (RCI and RCI*) are with respect to Option 1, no motorcycle regulation, with 12 percent of the motorcycle population modified since this represents the current estimate of modified motorcycles.

[3] These numbers are given to show the effect of a reduction in the number of modified motorcycles without concurrent reductions in the sound levels of new motorcycles.

The second type of activity interference examined is sleep awakening. The probability of sleep awakening is less than that for sleep disruption, since it takes more noise, generally of longer duration, to awaken a sleeper than it does to change the depth of sleep state.

For sleep awakening, the LWP and both RCI and RCI* results appear in Tables 5-24 through 5-26. These tables are organized identically to Tables 5-21 through 5-23. Again, the LWP values represent a composite of the number of people exposed, the number of passby events, and the probability of an interference occurring.

These tables show a very large reduction in potential sleep awakenings due to the regulation of motorcycle noise. The trends in RCI and RCI* for sleep awakening are nearly identical to the trends evidenced in Tables 5-21 to 5-23 for sleep disruption. For example, Options 9 and 10 show the most benefits in terms of RCI*, reaching by the year 2010 almost 45 percent assuming 12 percent modified motorcycles, and over an 85 benefit assuming 3 percent modified. The idealized option Q demonstrates little additional benefit.

Another type of activity interference examined is speech interference. Discussed separately is speech interference indoors at home, outdoors at home, and for pedestrians along streets.

For speech interference indoors, LWP, RCI and RCI* appear in Tables 5-27 through 5-29. Again, these tables are organized identically to the previous tables. These tables show very large benefits in terms of reduced speech interference due to the regulation of motorcycle noise. Some of the more important trends are noted below:

- Assuming no reductions in the number of modified motorcycles (12 percent level), the RCI becomes increasingly negative due to increases in motorcycle operations and U.S. population growth. This trend is offset somewhat with increasingly stringent source emission regulations.

- With no motorcycle regulation (Option 1), the RCI becomes increasingly negative even with a concurrent reduction in the number of modified motorcycles.

- The RCI values become increasingly positive as both the proportion of modified motorcycles is reduced and as increasingly more stringent source regulations are imposed.

- Options 9 and 10 demonstrate the greatest benefits in terms of RCI*. These benefits reach almost 30 percent in the year 2010 with no reduction in the proportion of modified motorcycles, and over 80 percent with an assumed three percent modified. The idealized Option Q shows little additional benefit. Options 1 and 2 show the least benefits to be gained.

- Benefits in terms of RCI* would reach, in the year 2010, approximately 32 and 58 percent by reducing the proportion of modified motorcycles to 7 and 3 percent, respectively, without concurrent source regulations.

- In terms of RCI*, benefits would reach in the year 2010 between 20 and 30 percent for the most stringent regulatory options even if the 12 percent proportion of modified motorcycles were not reduced.

TABLE 5-24

Sleep Awakening Impacts with 12 percent Modified Motorcycles

Regulatory Option	1980			1990			2000			2010		
	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]
Option 1	119.0	0.00	0.00	230.4	-93.61	0.00	321.9	-170.50	0.00	369.4	-210.42	0.00
Option 2	-	-	-	210.1	-76.55	8.81	293.0	-146.22	8.98	336.3	-182.61	8.96
Option 3	-	-	-	163.4	-37.31	29.08	222.4	-86.89	30.91	255.2	-114.45	30.91
Option 4	-	-	-	166.1	-39.58	27.91	222.4	-86.89	30.91	255.2	-114.45	30.91
Option 5	-	-	-	151.0	-26.89	34.46	196.5	-65.13	38.96	225.5	-89.50	38.96
Option 6	-	-	-	160.1	-34.54	30.51	196.6	-65.21	38.93	225.5	-89.50	38.96
Option 7	-	-	-	153.7	-29.16	33.29	196.5	-65.13	38.96	225.5	-89.50	38.96
Option 8	-	-	-	162.8	-36.81	29.34	196.6	-65.21	38.93	225.5	-89.50	38.96
Option 9	-	-	-	151.0	-26.89	34.46	177.6	-49.24	44.83	203.5	-71.01	44.91
Option 10	-	-	-	162.8	-36.81	29.34	181.9	-52.86	43.49	203.5	-71.01	44.91
Option Q	-	-	-	128.9	-8.32	44.05	171.1	-48.82	44.98	203.2	-70.76	44.99

NOTES:

[1] LWP = Level Weighted Population (millions)

[2] The relative changes in impact (RCI and RCI*) are with respect to Option 1, no motorcycle regulation, with 12 percent of the motorcycle population modified since this represents the current estimate of modified motorcycles.

TABLE 5-25

Sleep Awakening Impacts with 7 percent
Modified Motorcycles

Regulatory Option	1980			1990			2000			2010		
	LWP^{1}	RCI^{2}	RCI*^{2}	LWP^{1}	RCI^{2}	RCI*^{2}	LWP^{1}	RCI^{2}	RCI*^{2}	LWP^{1}	RCI^{2}	RCI*^{2}
Option 1	91.5^{3}	23.13	23.13	176.9^{3}	-48.66	23.22	247.3^{3}	-107.82	23.17	283.6^{3}	-138.32	23.23
Option 2	-	-	-	155.6	-30.76	32.47	216.9	-82.27	32.62	249.0	-109.24	32.59
Option 3	-	-	-	107.2	9.92	53.47	143.6	-20.67	55.39	164.8	-38.49	55.39
Option 4	-	-	-	110.0	7.56	52.26	143.6	-20.67	55.39	164.8	-38.49	55.39
Option 5	-	-	-	96.0	19.31	58.32	119.9	-0.76	62.75	137.7	-15.71	62.72
Option 6	-	-	-	104.2	12.44	54.77	120.0	-0.84	62.72	137.7	-15.71	62.72
Option 7	-	-	-	98.8	17.01	57.14	119.9	-0.76	62.75	137.7	-15.71	62.72
Option 8	-	-	-	107.0	10.08	53.56	120.0	-0.84	62.72	137.7	-15.71	62.72
Option 9	-	-	-	96.0	19.31	58.32	105.6	11.26	67.19	121.0	-1.68	67.24
Option 10	-	-	-	107.0	10.08	53.56	108.9	8.49	66.17	121.0	-1.68	67.24
Option Q	-	-	-	77.7	34.69	66.27	105.2	11.60	67.32	120.7	-1.43	67.33

NOTES:

[1] LWP = Level Weighted Population (millions)

[2] The relative changes in impact (RCI and RCI*) are with respect to Option 1, no motorcycle regulation, with 12 percent of the motorcycle population modified since this represents the current estimate of modified motorcycles.

[3] These numbers are given to show the effect of a reduction in the number of modified motorcycles without concurrent reductions in the sound levels of new motorcycles.

TABLE 5-26

Sleep Awakening Impacts with 3 percent Modified Motorcycles

Regulatory Option	1980			1990			2000			2010		
	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]
Option 1	68.7	42.30	42.30	132.8	-11.60	42.36	185.6	-55.97	42.34	213.1	-79.08	42.31
Option 2	-	-	-	110.8	-6.89	51.91	154.2	-29.58	52.10	177.0	-48.7	52.08
Option 3	-	-	-	60.9	48.82	73.56	78.9	33.67	75.48	90.7	23.82	75.46
Option 4	-	-	-	63.7	46.47	72.35	78.9	33.67	75.48	90.7	23.82	75.46
Option 5	-	-	-	50.8	57.34	77.96	57.4	51.75	82.16	65.9	44.63	82.16
Option 6	-	-	-	58.2	51.13	74.76	57.5	51.68	82.14	65.9	44.63	82.16
Option 7	-	-	-	53.5	55.03	76.78	57.4	51.75	82.16	65.9	44.63	82.16
Option 8	-	-	-	61.0	48.76	73.54	57.5	51.68	82.14	65.9	44.63	82.16
Option 9	-	-	-	50.8	57.34	77.96	46.7	60.75	85.49	53.5	55.08	85.53
Option 10	-	-	-	61.0	48.76	73.54	49.2	58.66	84.72	53.5	55.08	85.53
Option Q	-	-	-	35.3	70.48	84.75	46.3	61.07	85.61	53.2	55.33	85.61

NOTES:

[1] LWP = Level Weighted Population (millions)

[2] The relative changes in impact (RCI and RCI*) are with respect to Option 1, no motorcycle regulation, with 12 percent of the motorcycle population modified since this represents the current estimate of modified motorcycles.

[3] These numbers are given to show the effect of a reduction in the number of modified motorcycles without concurrent reductions in the sound levels of new motorcycles.

TABLE 5-27

Indoor Speech Interference Impacts with 12 percent Modified Motorcycles

Regulatory Option	1980			1990			2000			2010		
	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]
Option 1	22.5[3]	0.00	0.00	43.9[3]	-95.15	0.00	61.6[3]	-174.08	0.00	71.0[3]	-215.70	0.00
Option 2	-	-	-	42.3	-87.95	3.69	59.4	-163.98	3.68	68.4	-204.09	3.68
Option 3	-	-	-	37.6	-67.27	14.29	52.3	-132.55	15.15	60.2	-167.85	15.15
Option 4	-	-	-	37.9	-68.43	13.69	52.3	-132.55	15.15	60.2	-167.85	15.15
Option 5	-	-	-	35.7	-58.87	18.59	48.3	-114.72	21.66	55.6	-147.40	21.63
Option 6	-	-	-	37.1	-65.01	15.45	48.3	-114.76	21.64	55.6	-147.40	21.63
Option 7	-	-	-	36.0	-60.07	17.98	48.3	-114.72	21.66	55.6	-147.40	21.63
Option 8	-	-	-	37.4	-66.21	14.83	48.3	-114.76	21.64	55.6	-147.40	21.63
Option 9	-	-	-	35.7	-58.87	18.59	44.3	-96.89	28.16	51.0	-126.68	28.20
Option 10	-	-	-	37.4	-66.21	14.83	45.2	-100.93	26.69	51.0	-126.68	28.20
Option Q	-	-	-	31.6	-40.42	28.05	44.0	-95.69	28.60	50.7	-125.48	28.58

NOTES:

[1] LWP = Level Weighted Population (millions)

[2] The relative changes in impact (RCI and RCI*) are with respect to Option 1, no motorcycle regulation, with 12 percent of the motorcycle population modified since this represents the current estimate of modified motorcycles.

[3] These numbers are given to show the effect of a reduction in the number of modified motorcycles without concurrent reductions in the sound levels of new motorcycles.

TABLE 5-28

Indoor Speech Interference Impacts with 7 percent Modified Motorcycles

Regulatory Option	1980			1990			2000			2010		
	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]
Option 1	15.3[3]	32.01	32.01	29.9[3]	-32.77	31.97	42.0[3]	-86.53	31.94	48.3[3]	-114.94	31.92
Option 2	-	-	-	28.2	-25.34	35.77	39.6	-76.03	35.77	45.6	-102.93	35.72
Option 3	-	-	-	23.5	-4.49	46.46	32.5	-44.38	47.32	37.4	-66.43	47.28
Option 4	-	-	-	23.8	-5.69	45.84	32.5	-44.38	47.32	37.4	-66.43	47.28
Option 5	-	-	-	22.0	2.36	49.97	29.2	-29.79	52.64	33.7	-49.62	52.61
Option 6	-	-	-	23.1	-2.67	47.39	29.2	-29.84	52.63	33.7	-49.62	52.61
Option 7	-	-	-	22.2	1.16	49.39	29.2	-29.79	52.64	33.7	-49.62	52.61
Option 8	-	-	-	23.4	-3.82	46.80	29.2	-29.84	52.63	33.7	-49.62	52.61
Option 9	-	-	-	22.0	2.36	49.97	26.4	-17.16	57.25	30.3	-34.90	57.27
Option 10	-	-	-	23.4	-3.82	46.80	27.0	-20.05	56.20	30.3	-34.90	57.27
Option Q	-	-	-	18.8	16.45	57.19	26.1	-16.01	57.67	30.1	-33.66	57.66

NOTES:

[1] LWP = Level Weighted Population (millions)

[2] The relative changes in impact (RCI and RCI*) are with respect to Option 1, no motorcycle regulation, with 12 percent of the motorcycle population modified since this represents the current estimate of modified motorcycles.

[3] These numbers are given to show the effect of a reduction in the number of modified motorcycles without concurrent reductions in the sound levels of new motorcycles.

TABLE 5-29

Indoor Speech Interference Impacts with 3 percent
Modified Motorcycles

Regulatory Option	1980			1990			2000			2010		
	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]
Option 1	9.4[3]	58.15	58.15	18.4[3]	18.41	58.19	25.8[3]	-14.67	58.16	29.71[3]	-32.10	58.15
Option 2	-	-	-	16.7	26.19	62.18	23.4	- 3.96	62.07	26.95	-19.61	62.04
Option 3	-	-	-	11.9	46.91	72.80	16.2	27.88	73.69	18.70	16.85	73.66
Option 4	-	-	-	12.2	45.71	72.18	16.2	27.88	73.69	18.70	16.85	73.66
Option 5	-	-	-	10.7	52.47	75.64	13.6	39.75	78.02	15.63	30.50	77.99
Option 6	-	-	-	11.6	48.42	73.57	13.6	39.71	78.00	15.63	30.50	77.99
Option 7	-	-	-	11.0	51.31	75.05	13.6	39.75	78.02	15.63	30.50	77.99
Option 8	-	-	-	11.9	47.22	72.96	13.6	39.71	78.00	15.63	30.50	77.99
Option 9	-	-	-	10.7	52.47	75.64	11.7	48.02	81.04	13.44	40.24	81.07
Option 10	-	-	-	11.9	47.22	72.96	12.1	46.11	80.34	13.44	40.24	81.07
Option Q	-	-	-	8.3	62.92	81.00	11.4	49.27	81.49	13.15	41.53	81.48

NOTES:

[1] LWP = Level Weighted Population (millions)

[2] The relative changes in impact (RCI and RCI*) are with respect to Option 1, no motorcycle regulation, with 12 percent of the motorcycle population modified since this represents the current estimate of modified motorcycles.

[3] These numbers are given to show the effect of a reduction in the number of modified motorcycles without concurrent reductions in the sound levels of new motorcycles.

The results of the analysis for speech interference outdoors and for pedestrian speech interference are displayed in Tables 5-30 through 5-32 and Tables 5-33 through 5-35, respectively. The trends in these tables are nearly identical to the trends for indoor speech interference. For example:

- o For outdoor speech interference, Options 9 and 10 demonstrate the largest benefits, and Options 1 and 2 the least. By the year 2010, Options 9 and 10 show RCI* values of over 40 and 80 percent for assumptions of 12 and 3 percent modified motorcycles, respectively. Option Q shows some additional benefit.

- o For pedestrian speech interference in the year 2010, benefits in terms of RCI* for Options 9 and 10 reach over 65 and 85 percent for assumed 12 and 3 percent modifications, respectively.

- o For outdoor speech interference, RCI* benefits would reach by the year 2010 over 23 and 43 percent for assumed 7 and 3 percent modifications, respectively, even with no regulation of motorcycles. Likewise, for pedestrian speech interference benefits of over 8 and 14 percent are demonstrated.

- o For outdoor speech interference, RCI* benefits would by the year 2010 range over 30 to 40 percent for the most stringent regulatory options with no reduction in the proportion of modified motorcycles. Likewise, for pedestrian speech interference, benefits would range from 55 to over 65 percent.

5.9 Analysis of Noise Impact of Motorcycles Used Off-Road

This analysis adddresses the impact of regulations to limit the noise from motorcycles used off-road. Noise from off-road use of motorcycles is considered to be a problem of significant proportions. In a survey of 250 senior Federal and state managers of public lands, forests, lakes, parks, and wilderness areas of the United States regarding the adverse effects of off-road recreational vehicles (which include other factors besides noise), trail motorcycles were rated as the "most urgent problem for them to solve" (Reference 39). Minibikes (considered as motorcycles in this analysis) and snowmobiles (when in season) were listed as second and third priorities, with about one half the frequency of response.

In a survey that addressed public attitudes toward different noise sources, the largest number of respondents said they were "very much" annoyed by noise from trail motorcycles, even though motorboats, automobiles, and children were heard "more often" by respondents. A total of nearly 30 of the 113 people hearing trail motorcycles said they were "very much" annoyed, and approximately 10 of the remaining persons said they were annoyed "quite a lot" (Reference 40).

In a U.S. Forest Service study, seven experienced recreation guards at the Oregon Dunes National Recreation Area rated the noisiness of dune buggies as to acceptance by the public (Reference 41). While moving at 10 mph up a grade, the dune buggies were accelerated full throttle for a distance of 50 feet. The listeners were placed 50 feet from the midpoint of the accelera-

TABLE 5-30

Outdoor Speech Interference Impacts with 12 percent
Modified Motorcycles

Regulatory Option	1980			1990			2000			2010		
	LWP^1	RCI^2	RCI*^{2}	LWP^1	RCI^2	RCI*^{2}	LWP^1	RCI^2	RCI*^{2}	LWP^1	RCI^2	RCI*^{2}
Option 1	8.4	0.00	0.00	16.3	-95.31	0.00	23.1	-175.52	0.00	26.7	-218.67	0.00
Option 2	-	-	-	15.4	-84.20	5.69	21.7	-159.62	5.77	25.1	-200.26	5.78
Option 3	-	-	-	12.7	-51.69	22.34	17.5	-109.66	23.90	20.3	-142.17	24.01
Option 4	-	-	-	12.9	-53.60	21.36	17.5	-109.66	23.90	20.3	-142.17	24.01
Option 5	-	-	-	11.8	-40.57	28.03	15.6	-85.99	32.49	18.0	-114.56	32.67
Option 6	-	-	-	12.4	-48.70	23.87	15.6	-85.99	32.49	18.0	-114.56	32.67
Option 7	-	-	-	11.9	-42.80	27.05	15.6	-85.99	32.49	18.0	-114.56	32.67
Option 8	-	-	-	12.6	-50.49	22.95	15.6	-85.99	32.49	18.0	-114.56	32.67
Option 9	-	-	-	11.8	-40.57	28.03	13.7	-63.16	40.78	15.7	-88.14	40.96
Option 10	-	-	-	12.6	-49.41	22.95	14.1	-68.42	38.87	15.7	-88.14	40.96
Option Q	-	-	-	9.3	-11.51	42.91	12.9	-54.55	43.90	14.9	-78.46	43.99

NOTES:

[1] LWP = Level Weighted Population (millions)

[2] The relative changes in impact (RCI and RCI*) are with respect to Option 1, no motorcycle regulation, with 12 percent of the motorcycle population modified since this represents the current estimate of modified motorcycles.

TABLE 5-31

Outdoor Speech Interference Impacts with 7 percent Modified Motorcycles

Regulatory Option	1980			1990			2000			2010		
	LWP^1	RCI^2	RCI*^{2}	LWP^1	RCI^2	RCI*^{2}	LWP^1	RCI^2	RCI*^{2}	LWP^1	RCI^2	RCI*^{2}
Option 1	6.4^3	23.83	23.83	12.4^3	-48.70	23.87	17.6^3	-109.90	23.82	20.3^3	-142.77	23.82
Option 2	-	-	-	11.5	-36.98	29.87	16.2	-93.16	29.89	18.7	-123.52	29.86
Option 3	-	-	-	8.7	-3.44	47.04	11.8	-41.53	48.63	13.7	-63.52	48.69
Option 4	-	-	-	8.8	-5.36	46.06	11.8	-41.53	48.63	13.7	-63.52	48.69
Option 5	-	-	-	7.8	6.71	52.23	10.0	-20.01	56.44	11.6	-38.30	56.60
Option 6	-	-	-	8.4	-0.71	48.44	10.0	-20.01	56.44	11.6	-38.30	56.60
Option 7	-	-	-	8.0	4.81	51.26	10.0	-20.01	56.44	11.6	-38.30	56.60
Option 8	-	-	-	8.6	-2.59	47.47	10.0	-20.01	56.44	11.6	-38.30	56.60
Option 9	-	-	-	7.8	6.71	52.23	8.4	-0.73	63.44	9.7	-16.02	63.59
Option 10	-	-	-	8.6	-2.59	47.47	8.8	5.10	61.85	9.7	-16.02	63.59
Option Q	-	-	-	5.6	33.16	65.78	7.7	8.27	66.71	8.8	-5.77	66.81

NOTES:

[1] LWP = Level Weighted Population (millions)

[2] The relative changes in impact (RCI and RCI*) are with respect to Option 1, no motorcycle regulation, with 12 percent of the motorcycle population modified since this represents the current estimate of modified motorcycles.

[3] These numbers are given to show the effect of a reduction in the number of modified motorcycles without concurrent reductions in the sound levels of new motorcycles.

TABLE 5-32

Outdoor Speech Interference Impacts with 3 percent Modified Motorcycles

Regulatory Option	1980			1990			2000			2010		
	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]
Option 1	4.7[3]	43.50	43.50	9.2[3]	-10.39	43.48	13.0[3]	-55.87	43.43	15.1[3]	-80.49	43.36
Option 2	-	-	-	8.2	1.69	49.66	11.6	-38.66	49.67	13.4	-60.53	49.62
Option 3	-	-	-	5.4	35.81	67.14	7.2	14.15	68.84	8.3	0.88	68.90
Option 4	-	-	-	5.5	33.96	66.19	7.2	14.15	68.84	8.3	0.88	68.90
Option 5	-	-	-	4.6	45.19	71.94	5.5	33.85	75.99	6.4	23.74	76.07
Option 6	-	-	-	5.2	38.21	68.37	5.5	33.79	75.97	6.4	23.74	76.07
Option 7	-	-	-	4.7	43.23	70.94	5.5	33.85	75.99	6.4	23.74	76.07
Option 8	-	-	-	5.3	36.36	67.42	5.5	33.79	75.97	6.4	23.74	76.07
Option 9	-	-	-	4.6	45.19	71.94	4.2	50.33	81.97	4.8	42.89	82.08
Option 10	-	-	-	5.3	36.36	67.42	4.5	46.58	80.61	4.8	42.89	82.08
Option Q	-	-	-	2.5	69.64	84.46	3.4	59.68	85.37	3.9	53.57	85.43

NOTES:

[1] LWP = Level Weighted Population (millions)

[2] The relative changes in impact (RCI and RCI*) are with respect to Option 1, no motorcycle regulation, with 12 percent of the motorcycle population modified since this represents the current estimate of modified motorcycles.

[3] These numbers are given to show the effect of a reduction in the number of modified motorcycles without concurrent reductions in the sound levels of new motorcycles.

TABLE 5-33

Pedestrian Speech Interference Impacts with 12 percent Modified Motorcycles

Regulatory Option	1980			1990			2000			2010		
	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]
Option 1	16.3	0.00	0.00	32.0	-95.84	0.00	45.1	-177.40	0.00	52.2	-219.90	0.00
Option 2	-	-	-	29.2	-78.75	8.72	41.2	-151.99	8.82	47.7	-191.79	8.79
Option 3	-	-	-	19.2	-17.51	39.99	25.9	-58.30	42.72	29.9	-83.22	42.73
Option 4	-	-	-	19.8	-21.00	38.21	25.9	-58.30	42.72	29.9	-83.22	42.73
Option 5	-	-	-	16.3	0.43	49.16	19.6	-20.15	56.53	22.7	-38.82	56.60
Option 6	-	-	-	18.4	-12.68	42.46	19.6	-20.27	56.48	22.7	-38.82	56.60
Option 7	-	-	-	16.8	-3.06	47.37	19.6	-20.15	56.53	22.7	-38.82	56.60
Option 8	-	-	-	19.0	-16.17	40.68	19.6	-20.27	56.48	22.7	-38.82	56.60
Option 9	-	-	-	16.3	0.43	49.16	14.9	8.57	66.92	17.2	-5.21	67.11
Option 10	-	-	-	19.0	-16.17	40.68	16.0	2.02	64.55	17.2	-5.21	67.11
Option Q	-	-	-	8.7	-46.48	72.67	11.6	28.84	74.25	13.4	17.88	74.33

NOTES:

[1] LWP = Level Weighted Population (millions)

[2] The relative changes in impact (RCI and RCI*) are with respect to Option 1, no motorcycle regulation, with 12 percent of the motorcycle population modified since this represents the current estimate of modified motorcycles.

TABLE 5-34

Pedestrian Speech Interference Impacts with 7 percent Modified Motorcycles

Regulatory Option	1980			1990			2000			2010		
	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]
Option 1	15.1[3]	7.78	7.78	29.5[3]	-80.77	7.69	41.7[3]	-155.24	7.64	48.3[3]	-195.59	7.6
Option 2	-	-	-	26.6	-62.77	16.89	37.5	-129.52	16.95	43.4	-166.01	16.9
Option 3	-	-	-	16.1	1.71	49.81	21.4	-30.92	52.63	24.8	-51.68	52.6
Option 4	-	-	-	16.7	-1.96	47.94	21.4	-30.92	52.63	24.8	-51.68	52.6
Option 5	-	-	-	13.1	19.96	59.13	15.0	7.90	66.67	17.4	-6.49	66.7
Option 6	-	-	-	15.3	6.61	52.31	15.1	7.78	66.63	17.4	-6.49	66.7
Option 7	-	-	-	13.7	16.29	57.25	15.0	7.90	66.67	17.4	-6.49	66.7
Option 8	-	-	-	15.9	2.94	50.44	15.1	7.78	66.63	17.4	-6.49	66.7
Option 9	-	-	-	13.1	19.96	59.13	10.4	36.07	76.87	12.0	26.52	77.0
Option 10	-	-	-	15.9	2.94	50.44	11.5	29.64	74.54	12.0	26.52	77.0
Option Q	-	-	-	5.4	66.76	83.03	6.9	57.46	84.61	8.0	50.94	84.7

NOTES:

[1] LWP = Level Weighted Population (millions)

[2] The relative changes in impact (RCI and RCI*) are with respect to Option 1, no motorcycle regulation, with 12 percent of the motorcycle population modified since this represents the current estimate of modified motorcycles.

[3] These numbers are given to show the effect of a reduction in the number of modified motorcycles without concurrent reductions in the sound levels of new motorcycles.

TABLE 5-35

Pedestrian Speech Interference Impacts with 3 percent Modified Motorcycles

Regulatory Option	1980			1990			2000			2010		
	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]	LWP[1]	RCI[2]	RCI*[2]
Option 1	14.0[3]	14.39	14.39	27.4[3]	-67.91	14.26	38.7[3]	-137.23	14.16	44.9	-174.89	14.07
Option 2	-	-	-	24.4	-49.17	23.83	34.4	-110.47	23.84	39.9	-144.09	23.70
Option 3	-	-	-	13.4	17.76	58.01	17.7	-8.14	60.87	20.5	-25.35	60.82
Option 4	-	-	-	14.1	13.96	56.07	17.7	-8.14	60.87	20.5	-25.35	60.82
Option 5	-	-	-	10.4	36.19	67.42	11.2	31.23	75.12	13.0	20.33	75.10
Option 6	-	-	-	12.6	22.72	60.54	11.3	31.05	75.05	13.0	20.33	75.10
Option 7	-	-	-	11.0	32.39	65.48	11.2	31.23	75.12	13.0	20.33	75.10
Option 8	-	-	-	13.2	18.92	58.60	11.3	31.05	75.05	13.0	20.33	75.10
Option 9	-	-	-	10.4	36.19	67.42	6.7	58.85	85.11	7.7	52.76	85.23
Option 10	-	-	-	13.2	18.92	58.60	7.8	52.50	82.81	7.7	52.76	85.23
Option Q	-	-	-	2.7	83.52	91.59	3.1	81.13	93.17	3.6	78.24	93.20

NOTES:

[1] LWP = Level Weighted Population (millions)

[2] The relative changes in impact (RCI and RCI*) are with respect to Option 1, no motorcycle regulation, with 12 percent of the motorcycle population modified since this represents the current estimate of modified motorcycles.

[3] These numbers are given to show the effect of a reduction in the number of modified motorcycles without concurrent reductions in the sound levels of new motorcycles.

tion, perpendicular to the dune buggy path. The results of this experiment show that A-weighted sound levels ranging from 90 to 95 dB are the threshold of unacceptability to most users (Figure 5-16).

It is estimated that approximately one half of all recreational off-road vehicles (ORV) use in the United States takes place on lands administered by the Bureau of Land Management (BLM). BLM lands comprise some 20 percent of total U.S. land area, accounting for about 60 percent of all lands owned by the Federal government. Over half of ORV use takes place in the following areas: Alaska, western Arizona, southern California, southern Nevada, and central Utah.

5.9.1 Distribution of Off-Road Motorcycle Sound Levels

Sound levels of new non-competition off-road motorcycles are not largely dependent upon the size of the vehicle. Because of the limited sample size of off-road motorcycles, the assumptions used for street motorcycles in approximating the energy-average level from the median level is invalid. Therefore, the energy-average level is determined directly from the measured levels in Apppendix C. The data in Appendix C for new off-road motorcycles manufactured in 1975 and 1976 have an energy-average acceleration A-weighted sound level (SAE J-331a) of 92.5 dB at 50 feet. Off-road motorcycles with displacement of 170 cc are slightly lower.

Exhaust-modified off-road motorcycles are assumed to have the same SAE J-331a sound level distribution as exhaust-modified street motorcycles (shown in Figure 5-3), with a median acceleration sound level of 94 dB. The standard deviations for the unmodified and exhaust modified off-road motorcycles are assumed to be the same as those for street motorcycles (shown in Table 5-2).

Representative acceleration sound levels are assumed to be 3 dB lower than the SAE J-331a acceleration levels, the same assumption as was made for street motorcycles (see Appendix G).

In 1978, off-road mileage by motorcycles was approximately 12.0 million miles daily and was made up of contributions from street, dual-purpose, and off-road vehicles (Reference 42). Table 5-36 shows the off-road motorcycle mileage mix as estimated by the Motorcycle Industry Council (MIC). According to MIC, 50% of all off-road mileage in that year was accumulated by street and dual-purpose motorcycles. Thus, regulation of motorcycles designed for use on streets will have a significant effect on reducing the impact from off-road motorcycle usage. Representative acceleration sound levels from street and dual-purpose motorcycles were discussed in section 5.2.1.

The use of motorcycles that are designed for competition use in off-road areas also contributes to noise impact in such areas. A-weighted sound levels of competition-type motorcycles generally exceed 90 dB, with many exceeding 100 dB. Such levels dramatically increase the detectability distances of these vehicles (discussed in Section 5.9.2), resulting in relatively large land areas being impacted. Although the numbers of competition motorcycles that are used off-road are not known, most land management officials contacted by EPA reported that such vehicles constitute a very significant part of the

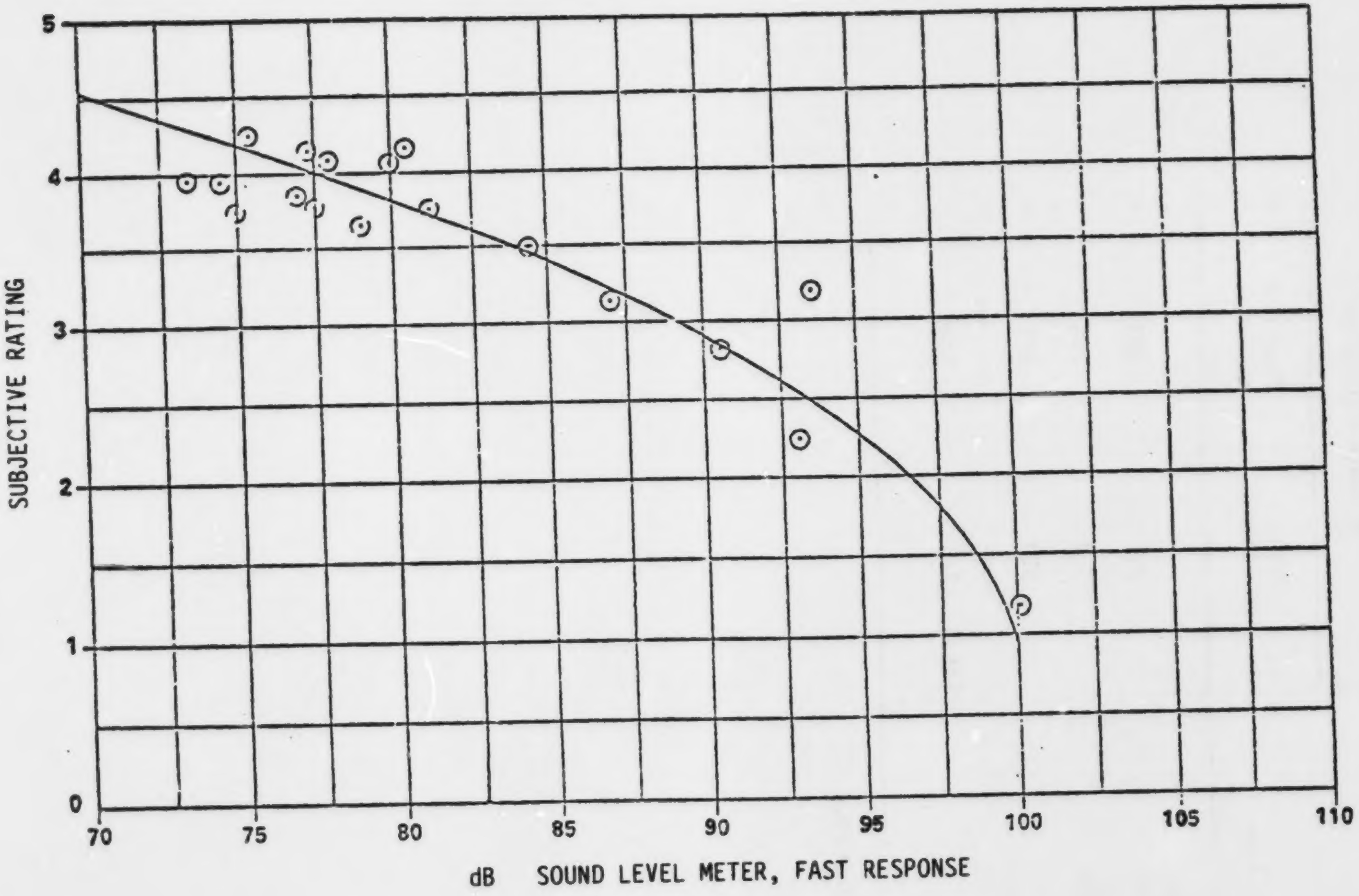

FIGURE 5-16 SUBJECTIVE NOISE RATING OF DUNE BUGGY NOISE LEVELS

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1) Very poor, noise completely unacceptable to almost all users.
2) Poor, noise unacceptable to most users.
3) Marginal, acceptable to most users.
4) Good, noise mildlly offensive to some users.
5) Excellent, noise not offensive to most users.

SOURCE: REFERENCE 21

TABLE 5-36 OFF-ROAD MOTORCYCLE MILEAGE MIX - 1978

Motorcycle Type	Mileage Estimates	
	Daily (Millions)	Fraction of Total
Street- Use (On-Highway)	2.7	22%
Dual-Purpose	3.3	28%
Off-Road (Off-Highway)	6.0	50%
	Total 12.0	100%

(Source: Reference 42)

off-road vehicle noise problem. Labels and other means of distinguishing competition motorcycles from off-road motorcycles, combined with well-planned and enforced land use restrictions, are considered to be the most effective means of dealing with the problem of competition motorcycles used in off-road areas.

5.9.2 Detectability Criteria

Off-road motorcycle operations often occur in areas with otherwise low ambient levels, near quiet suburban areas or more remote areas where people are hiking, camping, and pursuing other activities where man-made sounds are usually undesirable. In such situations, motorcycle noise is perceived by the listener as being alien to the environment and therefore an objectionable intrusion. For these reasons, "detectability" is considered to be the best descriptor of the impact of off-road motorcycle operations. In these situations, the criterion level for impact is the sound level at which a motorcycle can be discerned from the background by the listener, i.e., the minimum level at which it is detectable.

"Detectability distances" can be calculated for various types of vehicles in recreation areas with low ambient noise levels (References 43 and 44). Under "typical" forest conditions where the background A-weighted sound level is assumed to be 40 dB, detectability distances of 1400, 2600, and 3900 feet are reported for motorcycles with acceleration sound levels at 50 feet of 74 dB, 83 dB, and 93 dB, respectively (Reference 43). Detectability distance is defined as the distance at which 50 percent of the listeners with a "40 percent hearing efficiency" would detect a given sound level with a 1 percent false alarm rate. A "40 percent hearing efficiency" means a person not only has good hearing but is a "good listener," i.e., the person is listening carefully for the sound.

Because they are not necessarily concentrating on sounds, a more typical value of "hearing efficiency" for persons in remote or rural areas would be 20 percent. If a 20 percent efficiency is assumed, the above described detectability distances are reduced by a factor of about two (Reference 45). Therefore, detectability distances of 700, 1300, and 1950 feet from motorcycles with acceleration A-weighted sound levels of 74 dB, 83 dB, and 93 dB at 50 feet, respectively, are assumed to apply in quiet remote areas, with typical forest background levels of 40 dB. In other areas, such as campgrounds, small towns, and quiet suburban communities, the background sound levels are assumed to be on the order of 50 dB. In these areas, the detectability distances are reduced to approximately 400, 700, and 1150 feet from motorcycles for the same acceleration sound levels.

Figure 5-17 illustrates the assumed relationship between the detectability distances and the 50-foot acceleration sound levels in a 40 dB and a 50 dB ambient noise level environment. For purposes of analysis, it is assumed that all persons within the detectability distances will perceive the motorcycle noise and that none beyond the detectability distance will perceive the noise.

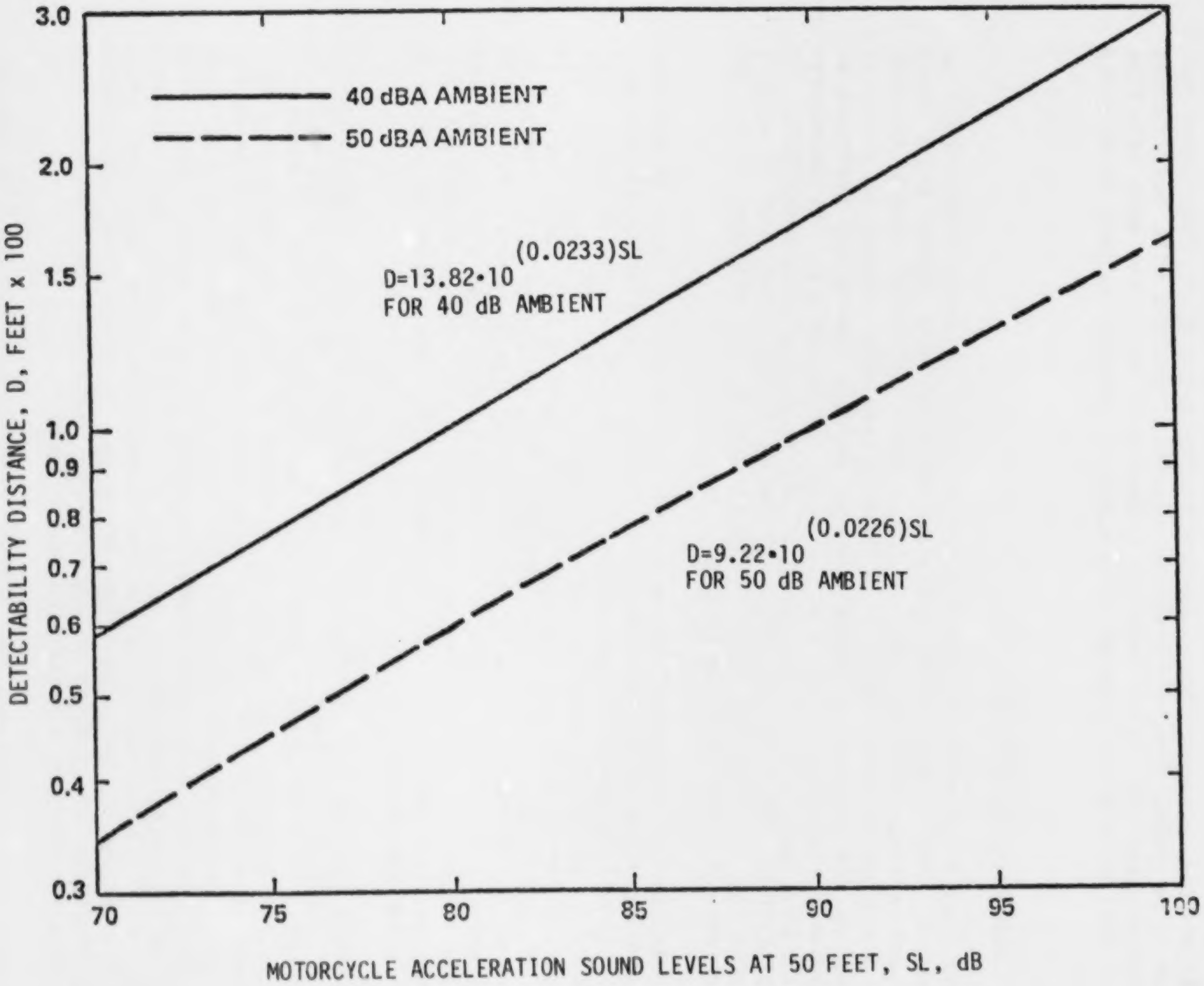

FIGURE 5-17. ASSUMED DETECTABILITY DISTANCE OF MOTORCYCLE SOUND IN 40 dB AND 50 dB AMBIENT NOISE LEVEL ENVIRONMENTS.

5.9.3. Off-Road Motorcycle Operations

Off-road motorcycle riding typically consists of numerous low-speed, near full throttle accelerations interspersed with quieter cruise and deceleration operations. Figure 5-18 illustrates two cases of interest: the case of a motorcycle being used on a trail or cross-country, and the case of a motorcycle operating within an ORV area where other ORVs are also likely to be operating at the same time. The circles indicate the distance from each acceleration at which noise exceeds a given criterion level, i.e., the criterion distance.

In the case of a motorcycle being operated on a trail, it can be seen that if the criterion distance is large enough so that it is a significant fraction of the straight-line distance between accelerations, the impacted area is approximately the sum of the straight-line distances between accelerations multiplied by double the criterion distance for the low-speed, high acceleration case. Detectability as a criterion satisfies this condition. Detectability distances for off-road motorcycle noise are on the order of one-half mile, which is typically a significant fraction of the straight-line travel distance. This model of a typical impacted area is assumed to apply for trail and cross-country riding. All persons within the impacted area are impacted at least once with noise above the criterion level.

For the case of motorcycles being operated in an off-road vehicle area, it is assumed that all persons within the boundaries of the area are ORV operators who are not greatly annoyed or otherwise impacted by ORV noise. Therefore, the impacted area would be the area bordering the ORV boundary that is within the criterion distance of the boundary, i.e., its size is the criterion distance multiplied by the approximate perimeter of the ORV area. It can be seen that the relative reduction in areas impacted above a criterion level when a motorcycle is quieted a given amount is the same for operations on the trail or a relatively large ORV area.

5.9.4 Estimate of Current Noise Impact

The impact of noise from off-road motorcycle operations requires a slightly different method to quantify "people impact" of off-road motorcycles than was used in the street motorcycle analysis. A model to estimate the impact was developed as described below.

For illustrative purposes, it can be assumed that, on the average, there are three motorcyclists riding together. Accordingly, three motorcycles operating together have the effect of reducing the total mileage by a factor of three (i.e., the total effective daily mileage becomes 40 million miles). Further, the combination of motorcycle types assumed to be operating together will affect the detectability distance. Since no data are currently available to determine the likely combination of motorcycle types, an equivalent motorcycle noise level is derived from available statistical data concerned with the usage and the noise levels of motorcycles operating in off-road areas.

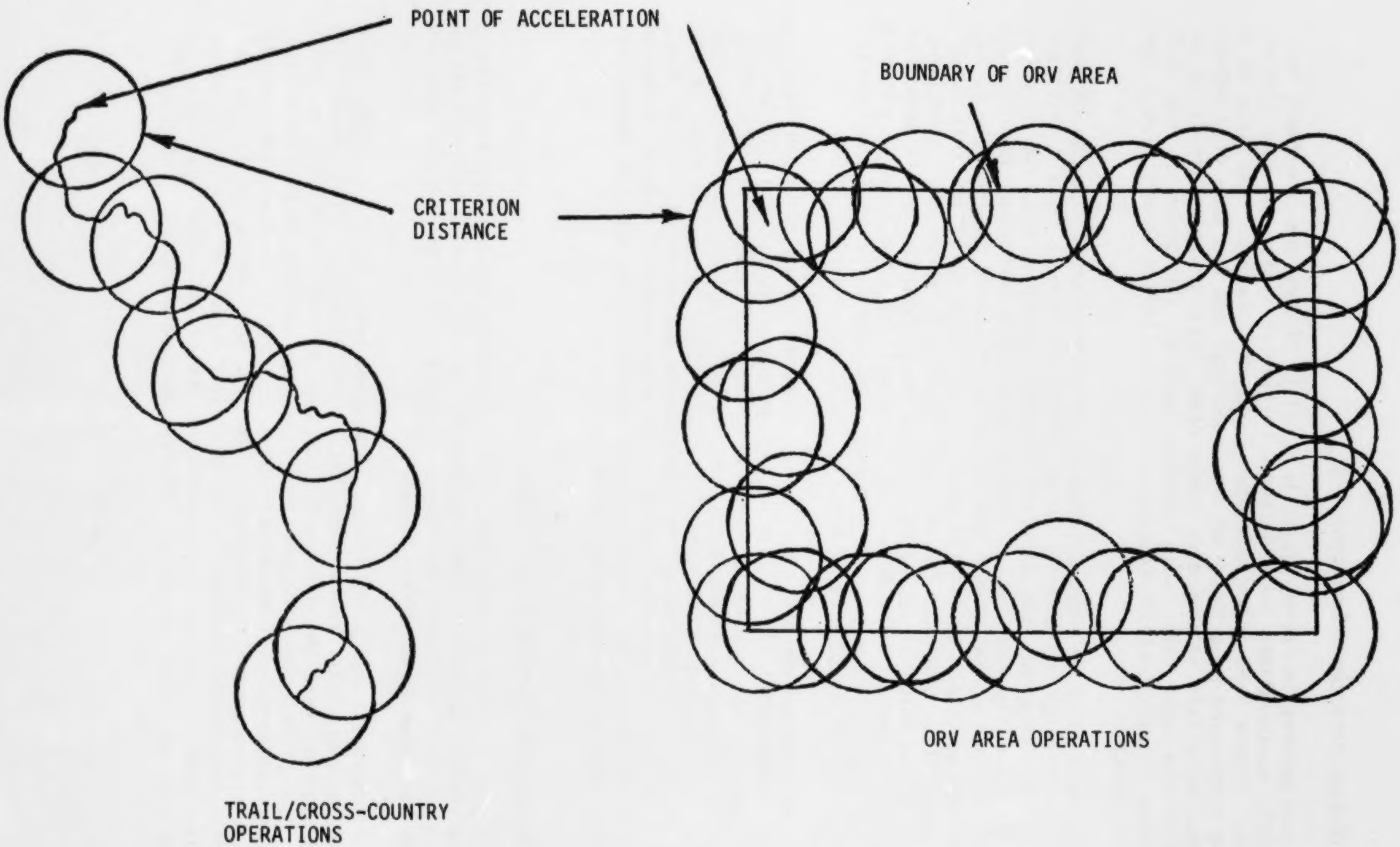
POINT OF ACCELERATION
CRITERION DISTANCE
BOUNDARY OF ORV AREA
TRAIL/CROSS-COUNTRY OPERATIONS
ORV AREA OPERATIONS

FIGURE 5-18. ILLUSTRATION OF OFF-ROAD OPERATIONS.

An equivalent noise level for all off-road usage is computed by summing, logarithmically, the "weighted" individual motorcycle noise levels produced by each of the types of motorcycles used off-road. The noise level weightings account for the distribution of off-road usage by motorcycle type and for the percentage of motorcycles with and without modified exhaust systems. The individual motorcycle noise levels and weightings used to compute the equivalent noise level are shown in Table 5-37. For example, the current levels are generated from street and dual-purpose motorcycles, making up 50 percent of the total, and off-road motorcycles, making up the other 50 percent Of the street and dual-purpose motorcycles, 88 percent have unmodified exhaust systems with an energy-average sound level of 79 dB (Section 5.2.1). The remaining 12 percent of the street and dual-purpose motorcycles have modified exhaust systems with energy-average A-weighted sound levels of 94.2 dB (Figure 5-3). The corresponding values of off-road motorcycles are 74 percent unmodified at 89.5 dB, and 26 percent modified at 94.2 dB (Figure 5-2) The equivalent noise level for this combination of unmodified and modified vehicles is 89.4 dB.

Again, for analytical purposes, it is assumed that, on the average there are three motorcyclists riding together. The three motorcycles operating together act as a single louder noise source. However, the detectability distance increases only about 30 percent when three sources with the same noise level are combined while effective daily mileage is reduced to one-third the total daily off-road motorcycle mileage. (The effect is a reduction in impact by a factor of about 23 due to the three motorcycles assumption.)

Three motorcycles operating together with individual noise levels of 89.4 dB (equivalent noise level for the combination of unmodified and modified motorcycles) act as a single source emitting 94.2 dB (an increase of 4.8 dB). When this eqivalent noise level is used for all off-road motorcycles, the resulting detectability distances for the 40 dB and 50 dB ambient noise level environments are determined to be 2157 feet and 1237 feet, respectively, from the curves shown in Figure 5-17.

As described above, the land area that is exposed daily to noise above the detectability levels is the product of the width of the detectability path (i.e., twice the detectability distance) and the effective daily off-road mileage (i.e., the total daily mileage divided by 3).

Because some of the daily off-road miles will overlap, i.e., the same or other motorcycles will impact the same area more than once, it is assumed that the land area exposed to motorcycle noise is reduced by a factor of 50. It is further assumed that approximately 95 percent of the total off-road mileage by motorcycles occurs in areas where the ambient noise level is typically 40 dB (such as forest and other rural areas) with the remaining 5 percent occurring in 50-dB ambient noise level environments (such as campgrounds, small towns, and quiet suburban areas).

Additionally, the population density of the areas with 40-dB and 50-dB ambient noise levels is assumed to be 20 and 1000 persons per square mile, respectively. On the basis of the above assumptions, it is estimated that approximately 64,000 square miles of land area and approximately 3.12 million people are exposed daily to noise above detectability levels from off-road motorcycle operations as shown in Table 5-38.

TABLE 5-37

MOTORCYCLE NOISE LEVELS AND WEIGHTINGS USED TO COMPUTE EQUIVALENT NOISE LEVELS; CURRENT NOISE IMPACT ANALYSIS

Motorcycle Type	Percent of Total Off-Road Motorcycle Usage	Percent With and Without Modified Exhaust System	A-Weighted Acceleration Noise Levels at 50 Ft. dB		
			Mean L_{50}	Standard Deviation	Energy-Average Equivalent L_a
Street and Dual-Purpose	50%	Unmodified Exhaust - 88%	77.4	3.7	79.0
		Modified Exhaust - 12%	91.0	5.3	94.2
Off-Road	50%	Unmodified Exhaust - 74%	**	**	89.5
		Modified Exhaust - 26%	91.0	5.3	94.2

Total Equivalent = 89.37

TABLE 5-38

ESTIMATED NOISE IMPACT IN 1978 FROM OFF-ROAD MOTORCYCLE USAGE

Type of Impact	Low Density 20 People/Sq. Mi	High Density 1000 People/Sq. Mi.	Total
Area Exposed (sq. miles)	62,100	1,900	64,000
People Exposed Above Detectability Level (millions)	1.24	1.88	3.12

5.10 Regulatory Schedules

Table 5-39 presents the regulatory options and parameters considered in this noise impact reduction analysis. For each regulatory year considered, two sets of data representing the percentage of off-road motorcycles with modified and unmodified exhaust systems are assumed in the anaylses, reflecting the effects of state and local enforcement programs on the percentage of motorcycles used off-road with modified exhausts.

Five basic regulatory options are presented in Table 5-39. Option 1 is the baseline, no regulatory condition. Option 2 represents a regulation effective in 1982 with a not-to-exceed A-weighted level of 83 dB for street and dual purpose motorcycles and 86 dB for off-road bikes. Similarly, Options 3 and 4, both effective in 1985, impose 80 dB limits on street and dual purpose motorcycles, with Option 3 specifying an 86 dB not-to-exceed level for off-road motorcycles, and Option 4 an 82 dB level. Option 5 is effective in 1990 and shows a 78 dB limit for street and dual purpose and 82 dB for off-road motorcycles. Not shown on Table 5-39, but included in the analysis, is Option Q (an idealized case) which represents the quieting of motorcycles to a level of 10 dB below the most stringent regulatory option. Option Q is included for comparison purposes to indicate an upper limit of benefits.

Each primary regulatory option is also broken into four subcategories labeled A, B, C and D in Table 5-39. Options A and B differ from C and D in that the latter options assume regulatory limits for off-road motorcycles less than 170 cc at the same production level as for street and dual purpose machines. In all cases, street and dual purpose motorcycles are assumed to constitute 50 percent of the total off-road motorcycles usage with the other 50 percent attributable to off-road motorcycles. In the cases of Options C and D, 37 percent of the usage is assumed to be from off-road motorcycles less than 170 cc, and 13 percent from bikes greater than 170 cc. Note also in Table 5-39 that Options A and C assume no enforcement at the state and local level (7 percent and 16 percent modified for street and dual purpose motorcycles and off-road motorcycles, respectively), while Options B and D assume complimentary state and local programs.

5.11 Results of Analysis - Off-Road Motorcycles

The section presents the results of the analysis to assess the relative reduction in current impact to be expected from the regulation of noise levels produced by motorcycles used off-road. When detectability distance is used as the noise impact criterion, the relative reduction in impact (RCI) is calculated in the same manner as was done for the street motorcycle analysis (see Equation 12).

Estimates of the impact resulting from the noise regulatory options for motorcycles used off-road are presented in Table 5-40. This table shows the off-road equivalent noise level at 50 feet calculated using the procedure outlined in Table 5-37, adjusted for the case of three motorcycles riding together. Also shown are the detectability distances computed for the 40 and 50 dB ambient conditions (from Figure 5-17), the estimated areas impacted (area of aural detectability of motorcycles), the number of people exposed daily within this area (includes assumptions of 20 and 1000 people per square mile for the 40 and 50 dB ambient conditions, respectively), and the relative change in impact from baseline. These noise impact estimates presented in

TABLE 5-39

PARAMETERS USED TO ASSESS THE NOISE IMPACT OF MOTORCYCLES USED OFF-ROAD

Regulatory Option Code	Year	Enforcement Program*	Motorcycle Type+	A-Weighted Regulatory Noise Level** (dB)	Percent of Total Off-Road Motorcycle Usage	Percent of Motorcycle Type With Modified Usage
1	1981	None	S,SX	None	50	12
			X	None	50	26
2A	1982	1	S,SX	83	50	7
			X	86	50	16
2B	1982	2	S,SX	83	50	3
			X	86	50	8
2C	1982	1	S,SX	83	50	7
			X<170cc	83	37	16
			X>170cc	86	13	16
2D	1982	2	S,SX	83	50	3
			X<170cc	83	37	8
			X>170cc	86	13	8
3A	1985	1	S,SX	80	50	7
			X	86	50	16
3B	1985	2	S,SX	80	50	3
			X	86	50	8
3C	1985	1	S,SX	80	50	7
			X<170cc	80	37	16
			X>170cc	86	13	16
3D	1985	2	S,SX	80	50	3
			X<170cc	80	37	8
			X>170cc	86	13	8
4A	1985	1	S,SX	80	50	7
			X	82	50	16
4B	1985	2	S,SX	80	50	3
			X	82	50	8
4C	1985	1	S,SX	80	50	7
			X<170cc	80	37	16
			X>170cc	82	13	16
4D	1985	2	S,SX	80	50	3
			X<170cc	80	37	8
			X>170cc	82	13	8
5A	1990	1	S,SX	78	50	7
			X	82	50	16
5B	1990	2	S,SX	78	50	3
			X	82	50	8
5C	1990	1	S,SX	78	50	7
			X<170cc	78	37	16
			X>170cc	82	13	16
5D	1990	2	S,SX	78	50	3
			X<170cc	78	37	8
			X>170cc	82	13	8

*1 = Federal regulation without state and local programs.
2 = Federal regulation with state and local programs.
+S = street, SX = dual purpose, X = off-road.
**Not-to-exceed noise levels as measured by EPA test procedures.

TABLE 5-40

ESTIMATED IMPACT RESULTING FROM VARIOUS NOISE REGULATORY OPTIONS FOR MOTORCYCLES USED OFF-ROAD

Regulatory Option Code From Table 5-39	Off-Road Equivalent 1/ Noise Level at 50 ft (dB)	Detectability, Distance, Ft		Noise Impact Estimates		
		40 dB Ambient (From Figure 5-17)	50 dB Ambient	Area Impacted (Sq. Miles)	People Exposed Daily Above Detectability Level (Thousands) 2/	Percent Reduction (RCI)
1	94.14	2,157	1,237	63,969	3,116	-
2A	90.67	1,790	1,032	53,094	2,595	16.73
2B	88.53	1,596	923	47,343	2,317	25.64
2C	90.43	1,768	1,020	52,442	2,563	17.75
2D	88.09	1,560	903	46,277	2,266	27.27
3A	90.49	1,774	1,023	52,620	2,571	17.47
3B	88.22	1,571	909	46,603	2,282	26.78
3C	90.12	1,739	1,003	51,582	2,521	19.08
3D	87.51	1,512	876	44,854	2,198	29.47
4A	90.08	1,736	1,002	51,494	2,518	19.20
4B	87.44	1,506	872	44,676	2,188	29.78
4C	90.01	1,728	998	51,257	2,507	19.54
4D	87.28	1,493	865	44,291	2,171	30.34
5A	90.01	1,728	998	51,257	2,507	19.54
5B	87.30	1,495	866	44,350	2,173	30.27
5C	89.88	1,717	991	50,931	2,491	20.07
5D	87.03	1,473	854	43,699	2,142	31.25
Q 2/	86.43	1,427	828	42,335	2,077	33.35

1/ Calculated using procedure outlined in Table 5-37, adjusted by 4.77 dB for three motorcycles riding together (see Section 5.9.4).

2/ Assumes 20 people per square mile in the 40 dB ambient condition, and 1000 people per square mile in the 50 dB ambient (see Section 5.9.4).

3/ Option Q represents a level 10 dB below the most stringent regulatory level.

Table 5-40 are made for conditions assuming that the entire fleet consists of regulated vehicles. This is different from the methods used to estimate the impact of street motorcycle noise (Section 5.8) where specified sales growth and depletion rates were used on a year-by-year basis. Note also that this analysis predicts the extent of impact only. No allowance has been made for the varying degrees of severity of exposure within the computed detectability areas. An artifact of this is that the RCI values presented in Table 5-40 may seem to be comparatively lower than those values computed (Section 5.8.2) using the single-event activity interference model which duly considers both the extent and severity of the impact. Nevertheless, relative comparisons between regulatory options for the analysis of motorcycles used off-road remain valid.

From Table 5-40, the results of the analysis show estimates of the area impact off-road ranging from over 42,000 square miles to about 64,000 square miles depending upon the regulatory option. Likewise, the number of people estimated to be exposed above the criterion level range from over 2,000,000 to over 3,000,000 people. All regulatory options provide significant lessening of impact relative to the base (no regulation) condition. Option 5 is typically the most effective in reducing impact, while Option 2 is the least effective. For example, Option 5A shows a 20 percent reduction in impact compared to a 17 percent reduction for Option 2A. Option Q shows only a slight additional benefit from that of the most stringent regulatory option examined (Option 5D).

The results in Table 5-40 also show that regulating off-road motorcycles under 170 cc to a less stringent level yields less benefit. For example, Option 4C show a 20 percent reduction in impact compared to the 19 percent benefit of Option 4A. On the other hand, the level of enforcement assumed has a very significant effect of benefits to be expected. For example, Option 4A with no complimentary state and local program would result in a 19 percent reduction in impact, while Option 4B with a concurrent program is anticipated to yield an almost 30 percent benefit. As was shown in the analysis of benefits of reducing noise from street motorcycles (Section 5.8), substantial benefits are shown as the number of modified motorcycles is decreased concurrent with source emission regulation.

REFERENCES

SECTION 5

1. "Constitution of the World Health Organization," WHO Office of Public Information, Geneva, Switzerland, 1948.

2. U.S. Environmental Protection Agency, "Public Health and Welfare Criteria for Noise," EPA Report 550/9-73-002, July 1973.

3. U.S. Environmental Protection Agency, Notice of Rulemaking for Medium and Heavy Truck Noise Emission Standards, Federal Register (41 FR 15538), April 13, 1976.

4. U.S. Environmental Protection Agency, Notice of Proposed Rulemaking for Bus Noise Emission Standards, Federal Register (42 FR 45776), September 12, 1977.

5. Survey of Motorcycle Ownership, Usage and Maintenance, A Gallup Organization, Inc. survey conducted for the Motorcycle Industry Council, Inc., Report GO 7458, January 1975.

6. Johnson, D.R., "A Note on the Relationship Between Noise Exposure and Noise Probability Distribution," National Physical Laboratory, NPL Aero Report Ac 40, May 1969.

7. Plotkin, Kenneth J., "Average Noise Levels for Highway Vehicles," Wyle Research Technical Note 79-2, September 1979.

8. U.S. Environmental Protection Agency, "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," EPA Report 550/9-74-004, March, 1974.

9. "Guidelines for Preparing Environmental Impact Statements on Noise," Report of Working Group 69, Committee on Hearing, Bioacoustics and Biomechanics, the National Research Council, Washington, D.C., 1977.

10. Schultz, Theodore J., "Synthesis of Social Surveys on Noise Annoyance," The Journal of the Acoustical Society of America, 64(2), 377-405, 1978.

11. Goldstein, Jeffrey, "Assessing the Impact of Transportation Noise: Human Response Measures", In Proceedings of the 1977 National Conference on Noise Control Engineering, G.C. Maling (Ed.), Noise Control Foundation, Poughkeepsie, N.Y., pp. 79-98, 1977.

12. Environmental Impact Statement for Proposed Noise Abatement Regulations, Noise Section, Department of Ecology, State of Washington, Olympia, WA 98504, 16 April 1975.

13. "Motor Vehicle Noise Identification and Analysis of Situations Contributing to Annoyance," Bolt Beranek and Newman Inc., Report 2082, June 1971.

14. Mills, C.H.G. and D.W. Robinson, "Appendix IX --- The Subjective Rating of Motor Vehicle Noise," *Noise --- Final Report*, Cmnd 2056 Her Majesty's Stationary Office, London, July 1963.

15. Report in preparation on community attitudes to noise in Boulder, Colorado, EPA regional office, Denver, Colorado.

16. Gunn, W., T. Shighehisa, and W. Shepherd, "Relative Effectiveness of Several Simulated Jet Engine Noise Spectral Treatments in Reducing Annoyance in a TV-Viewing Situation, NASA Langley Research Center, Draft Report, 1976.

17. Pearsons, K.S. and R.L. Bennett, "Effects of Interior Aircraft Noise on Speech Intelligibility and Annoyance," National Aeronautics and Space Administration Report, NASA CR-145203, August 1977.

18. Fidell, Sanford, "The Urban Noise Survey," U.S. Environmental Protection Agency Report No. 550/9-77-100, August 1977, and "Nationwide Urban Noise Survey", *The Journal of the Acoustical Society of America*, 64(17), 198-206, 1978.

19. Borsky, Paul N., "The Use of Social Surveys for Measuring Responses to Noise Environments" In *Transportation Noises: A Symposium on Acceptabilty Criteria*, J.D. Chalupnik (Ed.), University of Washington Press, Seattle, pp. 219-227, 1970.

20. "Noise-Final Report," Cmnd. 2056, Her Majesty's Stationary Office, London, July, 1963.

21. Grandjean, E., P. Graf, A. Lauber, H.P. Meier, and R. Muller, A Survey of Aircraft Noise in Switzerland, In *Proceedings of the International Congress on Noise as a Public Health Problem*, Dubrovnik, Yugoslavia, May 13-18, pp. 645-659, 1973.

22. Sorenson, S., K. Berglund, and R. Rylander, "Reaction Patterns in Annoyance Response to Aircraft Noise," In *Proceedings of the International Congress on Noise as a Public Health Problem*, Dubrovnik, Yugoslavia, May 13-18, pp. 669-677,1973.

23. Gunn, Walter J., "A General Discussion of 'Reactions to Aircraft Noises'," In *Reaction to Aircraft Noises: A Symposium Report*, E.A. Allvis (Ed.), *Journal of Auditory Research*, 15, Supplement 5, pp. 214-217, 1975.

24. Hall, F.L., S.M. Taylor, and S.F. Birnie, "Community Response to Road Traffic Noise", McMaster University, Hamilton, Ontario, Canada, December 1977.

25. McKennel, A.C., "Aircraft Noise Annoyance Around London (Heathrow) Airport", U.K. Government Social Survey Report SS.337, 1963.

26. Swing, John W., "A Case for Single-Event Intrusion Criteria in Achieving Noise-Compatible Land Use," *Noise Control Engineering*, 11(3), 98, 1978.

27. Allen, J.D., L.L. Faulkner, F.G. Ren, and A.M. White, "The Automobile As a Component of Community Noise," Phase 1 Final Report, Battelle Columbia Laboratories, June 1978.

28. Lukas, J., "Measures of Noise Level: Their Relative Accuracy in Predicting Objective and Subjective Responses to Noise During Sleep," U.S. Environmental Protection Agency Report No. EPA-600/1-77-010, February 1977.

29. Lukas, J., "Noise and Sleep: A Literature Review and a Proposed Criteria for Assessing Effect," The Journal of the Acoustical Society of America, Vol. 58 (6), pp. 1232-1242, 1975.

30. Plomp, R. and A. M. Mimpen, "Speech Reception Threshold for Sentences as a Function of Age and Noise Level," The Journal of the Acoustical Society of America, 66(5), 1333-1342, 1979.

31. Rudder, F.F., L. Ronk, and B.A. Hutcheson, "National Roadway Traffic Noise Exposure Model," Report prepared for the U.S. Environmental Protection Agency by Science Applications, Inc., 1979.

32. Ma, Y.Y., and F.F. Rudder, "Statistical Analysis of FHWA Traffic Noise Data", U.S. Department of Transportation, Federal Highway Administration, Report FHW-RD-78-64, July 1978.

33. Gray, R. F., "A Survey of Light Vehicle Operations", Engineering Publication 6313, General Motors Proving Ground, Milford, Michigan, July 1975.

34. Sakagami, J., "Consideration of Noise Emission of Road Vehicles on Urban Streets in Japan," Proceedings Inter-Noise 75, Tokyo University, Sendai 980, Japan, pp. 21-28, 1975.

35. "National Functional System Mileage and Travel Summary", U.S. Department of Transportation, Federal Highway Adminstration, Office of Planning, June 1977.

36. "National Highway Inventory and Performance Study Manual, 1976," U.S. Department of Transportation, Federal Highway Administration, July 1975.

37. "The Status of the Nation's Highways: Conditions and Performance," Report of the Secretary of Transportation to the United States Congress, 95th Congress, 1st Session, (45-29) U.S. Government Printing Office, September 1977.

38. "1970 Census of Population, Number of Inhabitants, United States Summary," U.S. Department of Commerce, Bureau of Census, December 1971.

39. Michael, J.J., "Research Briefs: A Final Summary of Attitudes of Senior Land and Recreation Managers in the United States Regarding Off-Road Recreation Vehicles," Parks and Recreation, 8(2):39-41, February 1973.

40. Shepherd, K.P., "A Preliminary Study of the Annoyance Due to Noise From Recreational Vehicles," Laboratory for Hearing Studies and Noise Control, University of Utah, Report T.R. 75-001, 1975.

41. Harrison, R., "Development of a Noise Standard for the Oregon Dunes National Recreation Area," U.S. Department of Agriculture, Forest Service, Equipment Development Center, San Dimas, CA, July 1973.

42. "1978 Motorcycle Statistical Annual," Motorcycle Industry Council, Inc., Research and Statistics Department, 1979.

43. Harrison, R.T., "Off-Road Vehicle Noise-Effects on Operators and Bystanders," U.S. Department of Agriculture, Forest Service, Report 740687, prepared for Society of Automotive Engineers, National Combined Farm, Construction and Industrial Machinery and Powerplant Meetings, Milwaukee, WI, September 9-12, 1974.

44. Fidell, S., K.S. Pearsons and R.L. Bennett, "Predicting Aural Detectability of Aircraft in Noise Backgrounds," Bolt Beranek and Newman Inc., Cambridge, MA, Report 220-AFFDL-TR-72-17, July 1975.

45. Harrison, R., private communication, U.S. Department of Agriculture, Forest Service, October 1976.

46. Harrison, R.T., "Sound Propagation and Annoyance Under Forest Conditions," U.S. Department of Agriculture, Forest Service, Equipment Development Center, San Dimas, CA, Report 7120-6, March 1974.

47. "1975 Automobile Facts & Figures", Motor Vehicle Manufacturers Association, Detroit, Michigan 48202.

48. "American Trucking Trends 1975," American Trucking Association, Inc., Washington, D.C. 20036, 1976.

49. Kent, P. and M. Branes: "1975 National Truck Characteristic Report", U.S. Department of Transportation, Federal Highway Administration, April 1978.

50. Galloway, W.J., K. Eldred, and M.A. Simpson, "Population Distribution of the United States as a Function of Outdoor Noise Level," U.S. Environmental Protection Agency Report No. 550/9-74-009A, June 1974.

51. Wyvill, C. (Ed.), "Discussion of Sound Propagation," Technical Meeting, U.S. Environmental Protection Agency, Office of Noise Abatement and Control, held at Crystal City, 14 October 1977.

52. "An Assessment of the Technology for Bus Noise Abatement," Booz Allen Applied Research, Draft Final Report submitted to U.S. Environmental Protection Agency, Office of Noise Abatement and Control, EPA Contract No. 68-01-3509, June 22, 1976.

53. Sutherland, L.C., "Indoor Noise Environments Due to Outdoor Noise Sources," Noise Control Engineering, 11(3), 124-137, 1978.

SECTION 6

NOISE REDUCTION TECHNOLOGY

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NOISE REDUCTION TECHNOLOGY

6.1 Diagnostic Evaluation of Noise Sources

Many of the manufacturers which EPA and its motorcycle technology contractor visited have performed and/or sponsored comprehensive diagnostic studies on motorcycle noise source contributions, and have defined the major noise-producing components and the levels of noise produced by these component sources both individually and in combination. The diagnostic techniques employed for identification of noise source contributions, and the specific noise control methods being employed or studied by the different manufacturers, were presented to the EPA on a confidential basis.* Table 6-1 shows the relative contribution of these sources for 21 1976 model motorcycles (as determined by the manufacturer of the vehicle), in three groupings: exhaust, intake, and mechanical. In this listing, "mechanical" encompasses noise radiated by the engine, power train, frame structure and equipment carried on the frame, and also tire and wind noise, the latter two being generally insignificant at current total vehicle noise levels. The vehicles are listed in descending order of total noise level (as measured by the J331a test); perusal of the table shows that the distribution of noise source contribution varies widely, and is independent of total noise level, use category, and engine type. There is also no relationship or trend between engine displacement and source contribution.

The noise reduction techniques necessary to meet a particular emission standard will vary widely from motorcycle to motorcycle, and are very difficult to place in a generally-applicable matrix of vehicle category/subcategory vs. noise level. For example (referring to the Table), to reduce noise emissions of vehicle "D" currently at 83 dB to 80 dB would require attention primarily to the exhaust which is contributing 84 percent of the noise; this might be attained relatively easily. On the other hand, for vehicle "H", currently at 82 dB, the attainment of an 80 dB level would require quieting the mechanical sources, which might constitute a major engineering effort.

6.2 Noise Reduction Technology

A review of the techniques which are in use or which can be selectively used to quiet motorcycles is presented in this section. No consideration is given to cost, nor to the suitability of these various techniques in relation to functional or aesthetic criteria.

Exhaust system quieting methods

Near term control of motorcycle noise emissions centers around the exhaust system, air intake system, and the mechanical/drive components. In approaching the noise reduction problem, manufacturers generally treat the exhaust and intake noise sources first because modification of these sources generally impact the basic model configuration least.

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* Most data was supplied by: Honda, Yamaha, Kawasaki, Suzuki and Harley-Davidson. Other manufacturers visited also supplied data used in this analysis.

Table 6-1

NOISE SOURCE CONTRIBUTION, 1976 MODEL MOTORCYCLES

Total Vehicle Noise Level dB	Vehicle Reference Letter	Category *		% Contribution of Noise Source		
		Use	Engine Type	Exhaust	Intake	Mechanical**
84	A	S	4S	60	3	37
83	B	S	4S	35	55	10
83	C	S	2S	24	30	46
83	D	SX	2S	84	5	11
82.5	E	S	4S	47	6	48
82	F	S	4S	30	35	35
82	G	S	2S	24	38	38
82	H	S	2S	6	4	90
82	I	S	2S	6	63	31
81	J	S	2S	11	50	39
80.5	K	SX	2S	28	31	41
80	L	S	4S	10	64	26
80	M	SX	4S	28	18	54
80	N	SX	2S	51	16	33
80	O	SX	2S	33	30	37
79.5	P	S	4S	25	18	57
79.5	Q	SX	2S	1	79	20
79.5	R	S	4S	32	35	33
79	S	S	4S	26	20	54
77.5	T	S	4S	66	20	14
77	U	SX	4S	42	22	36

* S denotes Street Motorcycle
SX denotes Combination Street and Off-road Motorcycle
2S denotes 2 stroke
4S denotes 4 stroke

** "Mechanical" includes engine, transmission, chain, frame, ancillary equipment, tires and wind noise.

Exhaust noise is generally reduced by using one or more of the following techniques: increasing muffler volume, adding reactive chambers/tubes, adding absorptive materials, restricting exhaust flow by baffles or perforated tubes, and dampening, stiffening, or isolating outer walls. Muffler volume can be increased by: physically enlarging the shell; interconnecting header pipes on multicylinder motorcyles (e.g., 4 into 1, 4 into 2 type systems), adding cross-pipes between dual exhaust systems where applicable, or combinations of these techniques. Interconnecting pipes change the impulse frequencies of the muffler in a favorable direction for improved effectiveness, but requires that reactive elements be properly designed for the changed frequency spectrum. In many cases redesign and modification of the muffler interior will reduce noise levels, generally at some penalty in increased backpressure. Such techniques include adding/ modifying reactive chambers, adding or sealing baffles, modifying the core pipe, inserting noise absorption lining and retaining walls, revising/ constricting exhaust flow, and adding elastic components. Dampening of the shell walls can be accomplished by use of laminated material, different material, or application of semi-viscous coatings. Stiffening of the shell walls can be accomplished by use of ribbing or internal bracing. Isolation can be accomplished by mounting components on elastomer supports. The latter modifications do not reduce noise emitted from the exhaust outlet, but reduce radiated noise from the muffler shell.

These techniques can be summarized:

- Increase muffler volume
- Interconnect exhaust pipes
- Modify interior
- Add noise absorptive lining
- Increase shell thickness/rigidity
- Construct double walls
- Isolate mounting

Application of these techniques is not at all straight-forward, and is in reality a very complex design problem. As an example, motorcycles with 2-stroke engines require optimally designed expansion chambers to assure proper exhaust scavenging and charging of cylinders. Modification of the exhaust system if improperly done could reduce performance drastically. Other modifications could create excessive back pressure, increase weight and fuel consumption or reduce motorcycle lean angle, balance, or ground clearance.

Intake system quieting methods

Air intake noise can be reduced by shielding or modifying the inlet duct, restricting or lengthening the intake path, increasing shell volume, adding baffles or absorptive materials, and dampening and/or isolating the intake shell. The shell dampening can be accomplished by the use of thicker or different material, reinforcement, or double wall construction. The techniques used to control air intake systems can be summarized as follows:

- Increase volume
- Modify inlet
- Modify interior
- Add noise absorption lining
- Increase wall thickness
- Construct double walls
- Shield inlet
- Reduce inlet area

Mechanical system quieting methods

The objective of mechanical redesign and rework is generally to reduce or contain engine and drive interaction noise (i.e., piston slap, valve clatter for 4-stroke models, gearing mesh, chain noise, etc.) and to reduce vibration (resonance) noise. The effort can be minor or major, depending on model peculiarities and degree of noise reduction required. Various techniques currently in use and mentioned by manufacturers as possibilities for future models are summarized as follows; and are described in the following paragraphs:

- Stiffen/dampen fins and case webs
- Change fin shapes
- Thicken/reinforce components
- Improve component mounting
- Thicken/reinforce case covers
- Isolate case covers
- Increase lubrication
- Modify piston/cylinder
- Reduce tolerances/improve finish
- Modify bearings
- Modify timing/drive belts/chains
- Stiffen crankshaft
- Redesign clutch and transmission
- Improve chain tensioner
- Enclose drive chain
- Dampen/isolate chain cover
- Stiffen/frame; isolate engine
- Lower engine speed
- Reduce specific horsepower
- Liquid cooling
- Convert 2-stroke to 4-stroke engine

- Modify camshaft
- Reduce valve clatter
- Increase flywheel mass
- Convert to shaft drive
- Reconfigure engine to reduce dynamic unbalance forces
- Use hydraulic torque converter
- Enclose engine

Stiffen/dampen fins and webs--Insertion of elastomer pads or metal dowels between radiating fins to reduce fin vibration.

Change fin shapes--modification or reinforcement of fins to reduce vibration.

Thicken/reinforce components--Modification or reinforcement to reduce vibration.

Improve component mounting--Use of gaskets and elastomer pads to isolate components to reduce vibration through metal to metal contact.

Thicken/reinforce case covers--Includes use of thicker material, reinforcement ribbings or double covers on such elements as gear covers, crankcase covers, camshaft covers and so forth.

Isolate case covers--Use of elastomers to reduce vibration and radiated noise.

Increase lubrication--Providing additional pressure lubrication to reduce mechanical interaction noise.

Modify piston/cylinder--Modify piston/cylinder configuration to reduce piston slap.

Reduce tolerances/improve finish--Reduce tolerances, or improve finishes of gears, bearings and so forth to reduce mechanical interaction noise.

Modify bearings--Replace ball and roller bearings with journal type bearings to reduce mechanical interaction noise.

Modify timing/drive belts/chains--Convert from chain drives to Hy-Vo, rubber or other types of quiet belts where applicable (e.g., timing belt change applicable to overhead cam engines).

Modify camshaft--Modify cam shape and increase shaft rigidity to reduce mechanical interaction noise.

Reduce valve clatter--Use of hydraulic lifters to eliminate tappet clearance (where applicable); incorporate elastomers to cushion tappet noise in overhead cam engines.

Increase flywheel mass--To reduce engine vibration.

Stiffen crankshaft--To increase rigidity and reduce mechanical interaction noise.

Redesign clutch and transmission--Use of helical gears instead of spur gears to reduce mechanical interaction noise; use of journal type bearings.

Improve chain tensioner--To reduce chain/sprocket interaction noise and chain tensioner noise.

Enclose drive chain--To attenuate drive chain noise.

Dampen/isolate chain cover--To eliminate cover vibration and radiated noise.

Stiffen/dampen frame; isolate engine--To prevent radiated noise due to engine vibration transmitted to the frame and to components mounted on the frame.

Lower engine speed--To reduce mechanical interaction noise.

Reduce specific horse-power--To reduce the excitation forces which result in engine noise radiation.

The above noise reduction techniques range from detail changes to significant redesign. For some models reductions in mechanical/drive noise levels to meet stringent noise standards would require techniques involving complete redesign of the engine and drive train. In addition, some of the techniques would result in reduced engine performance. As discussed in Section 4.1, it is impossible to predict by product categories which specific regulatory levels will require major model changes. The lowest levels that any of the manufacturers have reported as being feasible for the near-term is 80 dB for street motorcycles, 84 dB for off-road motorcycles. Other manufacturers question that an 80 dB noise standard can be met without major redesign on some models. Major model configuration changes could include the use of such techniques as conversion to liquid cooling, enclosing or covering the engine, conversion from a 2-stroke to 4-stroke engine (where applicable); use of a hydraulic torque converter for power transmission, conversion to shaft drive, engine re-configuration to reduce unbalance forces, or any other major engine/ drive redesign not specified here. These techniques would all require major changes in manufacturing operations, and extensive lead time. These techniques, not necessarily feasible in all use categories, are discussed in the following paragraphs.

Liquid Cooling--Liquid cooling, because it allows reduced clearances in engine parts, and because it provides added shielding around the engine cylinders, can materially reduce engine radiated noise. Conversion to liquid cooling would require re-engineering and re-tooling of the engine, add significant weight, and add to unit manufacturing costs. Additional hardware is required to implement liquid cooling, including a pump, radiator, thermostat, coolant, plumbing, instrumentation and recasting of the cylinder head and walls. Feasibility of liquid cooling for off-road motorcycles is very questionable because of vulnerability of the radiator to damage from rocks and spills.

4-Stroke vs. 2-Stroke Engines--Some manufacturers feel that 4-stroke engines are easier to quiet than 2-stroke engines. Because of this, conversion of engine types is a potential option. This alternative is also weighted by the fact that exhaust chemical emissions are more difficult to control in two-stroke engines, a factor currently of great concern to many manufacturers. It is unlikely that engine conversions would be made for noise control alone, due to the considerable engineering development and plant and equipment expenditures that would be required. In addition, direct manufacturing unit costs of 4-stroke engines are estimated by manufacturers to be more than those of equivalent sized 2-stroke engines.

Reduction of Unbalanced Forces--Unbalanced forces which cause engine and frame vibration are more severe in some engine configurations than in others. For example, unbalanced forces can be reduced by use of opposing cylinders, counter-rotating crankshafts, or balanced "V" configurations. These methods can involve dynamic vibration absorbers or counter-rotating balancing elements.

Shaft Drive--Shaft drive is an option that would reduce drive train noise on large (over 750 cc) and possibly medium sized (450-749 cc) on-road motorcycles. Shaft drive on models intended for some off-road use is less attractive, because of weight constraints and flexibility requirements in the drive train that are required for these models. Shaft drive affects many of the other components on the motorcycle, and is a relatively expensive option. A more cost-effective method of reducing drive noise in most cases would be to fully enclose the chain, which was identified previously as a noise reduction measure.

Hydraulic Torque Converter--Another technique that would involve major model configuration change is converting from a standard transmission to a hydraulic torque converter and a hydraulic gear engagement clutch, as exemplified by the transmission on the Honda CB 750A. Torque conversion by hydraulic means is basically quieter than by gears.

Engine Enclosure--Manufacturers indicated that if engine enclosure is considered as a noise control measure, it would generally be used in conjunction with liquid cooling. Enclosure or covering of air-cooled engines could create significant engine temperature control problems. In addition, some of the manufacturers feared that enclosure could drastically affect the marketability of motorcycles, since styling is an important factor affecting demand for motorcycles. Engine enclosure would entail added weight, and could hamper access for servicing.

Although there is no generally-applicable set of techniques that will achieve specified regulatory levels for a specific motorcycle, a matrix of techniques based on manufacturer-supplied information was developed for costing purposes. This matrix is presented in Table 6-2. For each regulatory level below 83 dB, a schedule of techniques other than major model changes are shown for each product class. Manufacturer information generally indicates that all techniques discussed above would be necessary to achieve a 75 dB level for models above 170 cc. Fewer of these techniques, or less extensive use of these techniques, are expected to be necessary at higher levels. For costing purposes two estimates were made at each study level below 83 dB: one assuming no major model change necessary, and one assuming a major model

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Table 6-2

NOISE REDUCTION TREATMENTS ASSUMED FOR EACH STUDY LEVEL
(J331a - NOT TO EXCEED BASIS)

	750 + cc				350 - 749 cc				170 - 349 cc				100 - 169 cc				100 cc			
EXHAUST SYSTEM	83	80	78	75	83	80	78	75	83	80	78	75	83	80	78	75	83	80	78	75
INCREASE MUFFLER VOLUME	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x		x	x	x
CROSS CONNECTIONS	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
MODIFY INTERIOR	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x
NOISE ABSORPTIVE LINING		x	x	x		x	x	x		x	x	x			x	x				
INCREASE SHELL THICKNESS		x	x	x		x	x	x			x	x			x	x			x	x
DOUBLE WALLS				x				x												
AIR INTAKE SYSTEM																				
INCREASE VOLUME	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x		x	x	x
MODIFY INLET	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x		x	x	x
MODIFY INTERIOR		x	x	x		x	x	x	x	x	x	x			x	x			x	x
NOISE ABSORPTIVE LINING		x	x	x		x	x	x		x	x	x				x				
INCREASE WALL THICKNESS		x	x	x		x	x	x		x	x	x				x				
MECHANICAL/DRIVE SYSTEM																				
STIFFEN/DAMPEN FINS/WEBS		x	x	x		x	x	x		x	x	x			x	x				
IMPROVED COMPONENT MOUNTING		x	x	x		x	x	x		x	x	x			x	x				
THICKEN/REINFORCE CASE COVERS		x	x	x		x	x	x		x	x	x			x	x				
INCREASE LUBRICATION			x	x			x	x			x	x				x				
MODIFY PISTON/CYLINDER			x	x			x	x			x	x				x				
REDUCE TOLERANCES/IMPROVE FINISH			x	x			x	x			x	x			x	x				
MODIFY BEARINGS			x	x			x	x			x	x				x				
MODIFY TIMING/DRIVE BELTS/CHAINS			x	x			x	x				x				x				
REDUCE VALVE CLATTER (4 STROKE)				x				x												
INCREASE FLYWHEEL MASS			x	x			x	x			x	x								
MODIFY CRANKSHAFT/CAMSHAFT				x				x												
MODIFY GEARS/TRANSMISSION				x				x				x								
TIGHTEN CHAIN				x				x				x								
ENCLOSE CHAIN				x				x				x								
MODIFY FRAME				x				x				x								

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change. As shown, the major model change assummed for street motorcycles is the use of liquid cooling. For off-road motorcycles, conversion to 4-stroke engines is assumed. Different individual models will of course require major model changes at different regulatory levels. A few are expected to require them at an 80 dB level, a substantial number are expected to need them at 78 dB, and virtually all are expected to need them at a 75 dB level.

6.3 Impacts of Noise Reduction Technology

6.3.1 Performance Impacts

Each of the techniques cited above can have impacts on motorcycle performance characteristics. Engine horsepower (including width of power band), torque, weight, lean angle, center of gravity, ground clearance and suspension characteristics can all be affected.

Power

All manufacturers cited engine power losses resulting from achieving current noise levels. Increasing power loss is expected at the lower levels studied. The power loss is generally attributable to restricted air intake and exhaust system back pressure. Table 6-3 indicates some of the data submitted to EPA pertaining to power losses involved in achieving current noise levels. From these data it is apparent that additional noise reduction measures will result in further power losses. Liquid cooling, with its potential for decreased engine tolerances, can abate this trend somewhat. Conversion from 2-stroke to 4-stroke engines will result in additional specific horsepower loss.

Weight

Many of the techniques cited may cause additional weight penalties. Modifications to the exhaust system could result in doubling current muffler weight or more, although the increasing use of 2 into 1, 3 into 1 and 4 into 1 exhaust systems on multicylinder motorcycles could abate this considerably. Similarly, more complex air intake systems might be expected to weigh more than current systems by factors of two or more. Mechanical noise quieting can be achieved through the use of thicker covers, improved mounting and increased mass of moving parts. The combination of these measures could increase engine weight by 10 to 15 percent. In addition, major engine modifications can result in a significant vehicle weight increase. One manufacturer estimated an increase of 10 percent in vehicle weight for liquid cooling (about 50 lb. for large motorcycles). Conversion of single cyclinder 2-stroke engines to single-cyclinder 4-stroke engines could cause an increase of up to 30 percent in total engine weight. Shaft drive mechanisms are quite heavy, but the lighter and less costly alternative of enclosure of the final drive chain will be assumed for the assessment of weight penalty.

6.3.2 Operation Impacts

The only significant impact of noise level reduction on operation costs should be a reduction in fuel economy. Increased weight, increased back pressure, power loss, and power required to drive auxiliary equipment (e.g., radiator pump) may all exact a fuel consumption penalty.

Table 6-3

POWER LOSS ASSOCIATED WITH ACHIEVING CURRENT LEVELS *

Motorcycle	Noise Level Reduction (dB)	Power Loss
a	4	12% over 6,000 RPM
b	4	2%
c	2	30%
d	2	30%
e	0.6	3%
f	2	1%
g	2	3%
h	2.5	28%
i	1.6	1%
j	3.5	10%
k	1	6%
l	8	up to 28%, 10% at peak
m	6 (approx)	12-15% (peak; very little below 4,000 RPM, severe roll off past peak)

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* Source: Confidential Manufacturer Data

It should be noted, however, that conversion from 2-stroke to 4-stroke engines could be expected to reverse this trend somewhat due to the slightly better fuel efficiency of 4-stroke engines.

From the previous section, the following vehicle weight increases are assumed (as a fraction of total vehicle weight):

		Regulatory Level				
	Over 170 cc	86dB	83dB	80dB	78dB	75dB
Street:	Straight forward change		0	2%	5%	10%
	Major model change		-	10%	15%	20%
Off-Road:	Straight forward change	0	2%	5%	10%	-
	Major model change	-	10%	15%	20%	-

100-169 cc : One-half of above figures
Less than 100 cc : 0% at all levels

Manufacturers supplied very little data on fuel economy impacts of achieving current or future noise levels. The little data that was furnished indicated that the 3 to 4 dB reductions to achieve current levels resulted in up-to-15 percent loss in fuel economy, although some models showed no change or an improvement. Experience with trucks and automobiles indicates that a 10 percent decrease in fuel economy for a 10 percent weight increase is a good assumption, but one which may tend to overstate the fuel economy penalty. Using this assumption, however, the above table can also serve to indicate the assumed fuel economy losses at the various regulatory levels when back-pressure and other penalties are included.

6.3.3 Maintenance Impacts

Several of the quieting techniques cited either require additional maintenance or make currently required maintenance somewhat more costly or more time consuming. Principal among the first of these are the minimal attention needed to keep a liquid cooling system in working order, and the additional maintenance associated with a switch from 2-stroke to 4-stroke engines. Complex mounting techniques, additional covers, reduced engine tolerances, valve train complexities and enclosed final drive will complicate routine maintenance. No definitive data on the maintenance impacts of these techniques are available. For the purposes of analysis the following additional annual maintenance time (in hours) is assumed:

		Regulatory Level				
	Over 170 cc	86dB	83dB	80dB	78dB	75dB
Street:	Straight forward change	-	0	1/4	3/8	1/2
	Major model change	-	-	3/4	7/8	1
Off-Road:	Straight forward change	0	1/4	3/8	1/2	--
	Major model change	-	3/4	7/8	1	--

100-170 cc : One-half of above figures
Under 100 cc : Zero at all levels

Noise reduction will affect cost of maintenance and replacement parts only through increased cost for replacement exhaust systems.

6.3.4 Aesthetic Factors

To many motorcyclists the aesthetic impacts of noise reduction technology may be even more important than performance or cost impacts. Many of the above techniques can be expected to have an adverse impact on the sleek and sporty styling of current models. Larger mufflers, frame reconfigurations to accomodate larger air intake systems, bulkier engines and liquid cooling all pose styling problems. Although these factors are unquantifiable, they are felt to have potential sales impacts independent of the cost and performance factors cited above.

6.4 Production Variations

The noise levels of all nominally identical surface transportation products exhibit a distribution covering a range of several decibels. Since EPA's regulations are on a not-to-exceed basis, manufacturer design and production must account for this distribution of noise levels to assure compliance with the standards. This is in addition, of course, to factors accounting for testing variables. Manufacturers supplied EPA with data on the production variation exhibited by certain of their models. These data are displayed in Table 6-4. From these data it is concluded that manufacturers will have to produce vehicles at least 1 1/2 dB below an applicable standard to account for production variations.

Table 6-4

PRODUCTION VARIATION

Manufacturer	Production Variation (dB)
a	$2\sigma = 3\text{-}4$
b	1.5 - 2.5
c	$1\sigma = 0.25 - 0.6$
d	2-stroke: 1.5 4-stroke: 2.0
e	1.5

Source: Manufacturer Confidential Data

6.5 "Best Available Technology"

Each of the quieting techniques discussed in Section 6.2 exist either in current production models or in prototypes in advanced states of development. As such, their combined use represents "best available technology" for motorcycles. Large and complex exhaust and intake systems have been demonstrated on a wide variety of production vehicles. Weight, positioning, and performance penalties are the only technological limits to larger and more complex units. There are numerous examples of current motorcycles either with large muffler volume in relation to engine displacement or sophisticated muffling of multicylinder engines. Double-wrapped mufflers have been used in several models and prototypes, and at least one prototype known to EPA uses a major engine frame member for its air intake reservoir.

Many of the engine quieting techniques discussed previously exist in current production engines. Recent models from the major manufacturers have demonstrated significantly reduced engine mechanical noise. Balanced (90-degree) V-twin engines have been well demonstrated.

The past five years of motorcycle development has seen an increasing number of multi-cylinder engines with high specific horsepower. This specific horsepower has often been achieved by increased engine speed, which has resulted in increased engine mechanical noise. The testing program data base shows the critical importance of engine speed to engine noise. Decreased engine speed at a loss of specific horsepower is available to all manufacturers of high RPM engines.

Liquid cooling has been well demonstrated on several production models, both 2-stroke and 4-stroke. Liquid cooling for a complete line of smaller 2-stroke motorcycles (down to 50 cc) has been demonstrated by one European manufacturer.

Shaft-drive has been well demonstrated on motorcycles 500 cc and above.

Based on an examination of motorcycle models incorporating the techniques discussed above, EPA has concluded that the 78 dB regulatory level (SAE J331a), requiring a 75 dB design level, is the level representative of "best available technology" for street motorcycles. The Honda GL-1000, generally acknowledged to be the quietest large motorcycle ever produced, already incorporates many of the major techniques listed above (liquid cooling, shaft drive, very large intake and exhaust systems). Even this motorcycle would require some small additional quieting to meet a 78 dB level on a production basis.

"Best available technology" for off-road motorcycles is a question both of technology and performance. Although motorcycles with off-road capability can be built at levels almost as low as for street motorcycles, such motorcycles demonstrate significant performance penalties. Weight, power, power band width and ground clearance are all of crucial importance to off-road motorcycles. Each of these factors on an off-road motorcycle can be more significantly impacted at lower noise levels than for street motorcycles of comparable displacement. The inappropriateness of applying liquid cooling to off-road motorcycles leads to different levels of "best available technology" for large and small off-road motorcycles. Small off-road motorcycles (under 170 cc) are expected to be able to achieve the same levels achievable by their street counterparts. Large off-road motorcycles, however, without the option of liquid cooling cannot achieve the same levels as their street counterparts (exacerbated by the fact that most street motorcycles over 170 cc have multicylinder engines, whereas off-road motorcycles must be single cylinder). Both small and large off-road motorcycles can currently meet the 86 dB level. To meet levels at 80 dB and lower, conversion from 2-stroke to 4-stroke engines may be necessary for large off-road motorcycles. An 82 dB level can be met by large off-road motorcycles without conversion to 4-stroke engines. EPA has concluded that this 80 dB regulatory level constitutes "best available technology" for the large off-road motorcycles and 78 dB for small off-road motorcycles. It is understood that although these levels are achievable, the performance of large 2-stroke off-road motorcycles will be reduced significantly in many cases.

Although all of the techniques constituting "best available technology" exist in production or prototype motorcycles, not all manufacturers have the capability of incorporating them into their motorcycles. Particular problems exist with manufacturers that have uniquely identifiable engine types that can be fundamentally changed only with a serious impact on marketing position (Harley-Davidson, BMW, Moto Guzzi, Ducati), manufacturers whose products have been developed from racing motorcycles and depend on high performance (Laverda) smaller manufacturers of high-performance off-road motorcycles (Can-Am, Husqvarna, Bultaco, etc.) and small manufacturers without large R&D capability (NVT Motorcycles and the very small U.S. manufacturers).

6.6 Lead Times

In the absence of certification for air emissions, manufacturers generally indicated the following lead times were necessary to make changes on an individual motorcycle model (total time, drawing to production): Changes to exhaust or air intake system that do not require frame or engine redesign--one year; changes requiring frame redesign or minor engine redesign--two to three years; major engine redesign--four to five years;new engine model, new engine concept, conversion to 4-stroke engine--five to six years (and up). Limited R&D resources, however, allow redesign of only a few models per year. Major manufacturers with extensive product lines would require additional time to be able to redesign models on a more or less orderly basis. In addition, air emission certification can add one half to one year to required lead times for major manufacturers due to required durability runs. Manufacturers emphasized the need to coordinate effective dates of these regulations to eliminate unnecessary recertification for air emissions when redesign for noise purposes takes place.

Based on this information the following lead times are felt to be achievable by major manufacturers, consistent with orderly redesign of an extensive product line (years from promulgation):

		Regulatory Level (SAE J331a)				
		86 dB	83 dB	80 dB	78 dB	75 dB
Street:	Straight forward change	--	1	2	4	6
	Major model change	--	--	4	6	10
Off-Road:	Straight forward change	1	2	4	6	--
	Major model change	--	4	6	10	--

An accelerated schedule of lead times can be considered which would require simultaneous redesign of many models. Manufacturers insisted that resources were unavailable for orderly redesign on this basis. The following is an "accelerated" schedule of lead times which might be achievable at considerably increased R&D costs:

		Regulatory Level (SAE J331a)				
		86 dB	83 dB	80 dB	78 dB	75 dB
Street:	Straight forward change	--	--	1	3	5
	Major model change	--	--	3	5	7
Off-Road:	Straight forward change	1	2	3	5	--
	Major model change	--	3	5	7	--

Different manufacturers, of course, have different lead time requirements. Noise levels of current models (particularly the mechanical contributions), available funds for R&D, size of product line, and familiarity with 4-stroke or liquid cooling technology, all have a bearing on individual lead time requirements. The "normal" lead time schedule cited above is most appropriate for the major Japanese manufacturers other than Honda. The noise levels of Honda's current product line would probably allow somewhat shorter times. Harley-Davidson, Can-Am and the European manufacturers would all be severely tested to meet the same time schedule as the major Japanese manufacturers, for a variety of reasons relating to unique engine designs, exclusive use of 2-stroke engines or company size (availability of R&D capital). If these other manufacturers would be strained at the "normal" schedule, it is reasonable to conclude that they would probably not be able to comply with the "accelerated" schedule.

6.7 Deterioration of Motorcycle Noise Levels

Most manufacturers supplied limited data on experience with motorcycle noise levels during mileage and time accumulation. Several engineering reasons were discussed as to why motorcycle noise levels ought to decrease with usage, at least at first. After the initial breakin period, mechanical interaction noise can abate as parts fit together better. Muffler noise can decrease as carbon build-up seals small openings left from the manufacturing process.

Properly designed all-metal mufflers can last a considerable period of time before noise level deterioration occurs, depending on climate and operating conditions. Properly designed mufflers with glass inserts can also last a significant length of time, although poorly designed ones can deteriorate rapidly. European standards make a distinction between mufflers that direct exhaust gases through fibrous material and mufflers that reflect exhaust gases into but not through the fibrous elements. Some manufacturers specify replacement of fibrous elements or replacement of the exhaust system when deterioration occurs At least one manufacturer supplies free replacement fiberglass for his mufflers.

In general, manufacturers supplied no engineering reasons why a properly maintained and operated motorcycle should experience significant noise emission deterioration over its lifetime. "Properly maintained" in this context means replacement of parts (including such major parts as mufflers) as needed according to the operation instruction. Deterioration data for a few models is displayed in Table 6-5.

6.8 Relationship to Air Emission Control

A number of manufacturers expressed serious concerns that at strict levels of air emission controls there may be a significant tradeoff between air pollution control and noise control. At the levels established in EPA's final rule on motorcycle air emissions this concern has abated somewhat.

The higher temperatures of exhaust gases due to air emission control may have a dual effect on exhaust noise emissions. Higher temperature gas is less dense, requiring a higher rate of flow for equivalent performance. In addition, the higher temperature gas has more inherent energy which must be dissipated. Both of these effects would tend to raise exhaust noise. One manufacturer cited a study on automotive air emission and noise control which showed noise level increases of up to 4 dB at strict levels of emissions control.

A second effect of higher engine temperatures is the need for larger surface areas to dissipate heat from an air cooled engine. These larger surfaces, in turn, can increase noise radiation. Liquid cooling, of course, would in large part counteract the higher engine and exhaust temperature increases due to air emission control.

One manufacturer indicated that the increased length and complexity of an air intake path could cause fluctuations in air/fuel mixture with a corresponding adverse impact on air emissions.

6.9 Technology to Achieve Noise Levels Based on Different Measurement Methodologies

Technology and costing information supplied to EPA by manufacturers and developed by EPA contractors have been based on study levels specified in terms of the SAE J331a test procedures. As discussed in Section 3, the F-76a test procedure is felt to be statistically equivalent to SAE J331a across a broad range of motorcycles although individual models may vary up or down by several dB. The manufacturer-supplied information was based on several models of each of the manufacturer's lines. The SAE J331a and F-76a noise levels of each of the models used for these purposes were compared to determine whether these vehicles represented anomalous cases in the SAE J331a/F-76a relationship. Of 15 models used for technology and costing purposes, ten showed differentials of less than 2 dB, one showed a differential of 2 dB, and four showed differentials of 3 dB. However, the models displaying differentials of 2 dB or greater showed no consistent pattern with as many higher under one procedure as the other. The cost information in the succeeding chapters was checked carefully and it was found that overall values do not change significantly as a study level specified in terms of SAE J331a is translated into a study level specified in terms of F-76a.

Table 6-5

DETERIORATION OF MOTORCYCLE NOISE LEVELS

Model	Deterioration (dB)	Mileage
a	2-4	10,000
b	±1	6,250
c	∓1 1/2	6,250
d	±1 (peak +2)	6,250
e	∓0-	6,250
f	right side: 0	6,250
	left side: +1	6,250
g-k (muffler only, 5 models)	-0.33* to -1.6/6.250 mi	up to 1[illegible],000
l	-1 1/2 (+1; -1/2)	7,160
m	-1 1/2 (±1/2)	3,240

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* A negative number indicates a reduction in noise level.

Source: Manufacturer Confidential Data

SECTION 7

COSTS OF COMPLIANCE

SECTION 7

COST OF COMPLIANCE

7.1 Unit Cost Increases

In complying with the motorcycle noise regulation, manufacturers will experience increased costs of manufacturing (production) as well as the costs of research and development, tooling, and testing/certification. This increase in costs will lead to increases in the unit cost (price) of new motorcycles. The price of new replacement exhaust systems will also increase for similar reasons.

Unit cost increases are expected to vary with the type (function) and size category of motorcycle, and the stringency of the applicable noise standard itself. The most significant difference in compliance costs will appear when vehicles, requiring relatively "straight forward" model changes, are compared with those requiring "major" model changes.

Model changes considered straight forward include increasing muffler volume, adding lining to the air-intake system, or stiffening fins and webs of the engine casing. Major model changes include the use of any noise control techniques that require extensive R&D, substantial model redesign and production tooling modifications, or significant increases in unit manufacturing costs. A more complete listing of motorcycle noise control techniques is provided in Table 7-1. These were cited by manufacturers as ones necessary to meet the lower (more stringent) study levels.

There is a high degree of uncertainty as to which motorcycle models (and for which manufacturers) major changes will be necessary. As a result, two cases were analyzed; (1) the nominal (expected) case, and (2) the worst case. With some assumptions, data from manufacturers (including current motorcycle noise source data) were used to estimate the fraction (expressed in percent) of motorcycle production requiring major model changes at various regulatory levels. The results for the two cases are presented in Table 7-2.

For street motorcycles, the percentages in Table 7-2 apply to all size categories above 100 cc (no major model changes are expected below 100 cc) For off-road motorcycles, however, different percentages apply to different size categories. This is due to the limited use to which liquid cooling has been used for off-road motorcycle engines and the fact that virtually all such engines are single cylinder. Larger off-road motorcycles are expected to require major model changes (4-stroke conversions) at higher regulatory levels than smaller off-road types. The estimated distribution of percentages of major model changes for off-road motorcycles are shown in Table 7-3 (worst case percentages are in parentheses).

By using the estimated percentages for major model changes in Tables 7-2 and 7-3, the nominal and worst case total unit cost increases can be calculated once the individual cost elements (e.g., for manufacturing, R&D, tooling, testing and compliance) are known for each vehicle type and displacement category. Total costs are summarized in Table 7-4. Further aspects of total unit costs and cost element breakdowns are given in Section 7.1.1.2.

Table 7-1

NOISE CONTROL TECHNIQUES

EXHAUST SYSTEM	INCREASE MUFFLER VOLUME
	CROSS CONNECTION
	MODIFY INTERIOR
	SOUND ABSORPTION LINING
	INCREASE SHELL THICKNESS
	CONSTRUCT DOUBLE WALLS
	ISOLATION MOUNTING
AIR INTAKE SYSTEM	INCREASE VOLUME
	MODIFY INLET
	MODIFY INTERIOR
	ADD SOUND ABSORPTION LINING
	INCREASE WALL THICKNESS
	DOUBLE WALLS
	SHIELD INLET
	REDUCE INLET AREA
MECHANICAL/DRIVE SYSTEM	STIFFEN/DAMPEN FINS AND WEBS
	CHANGE FIN SHAPES
	COMPONENT MOUNTING
	THICKEN/REINFORCE CASE COVERS
	INCREASE LUBRICATION
	MODIFY PISTON/CYLINDER
	REDUCE TOLERANCES/IMPROVE FINISH
	MODIFY BEARINGS
	MODIFY TIMING/DRIVE BELTS/CHAINS
	REDUCE VALVE CLATTER (4-STROKE)
	INCREASE FLYWHEEL/CAMSHAFT
	MODIFY CLUTCH
	MODIFY GEARS/TRANSMISSION
	TIGHTEN DRIVE CHAIN
	MODIFY FRAME
	ISOLATE CHAIN COVER
	LOWER ENGINE SPEED
	REDUCE SPECIFIC HORSEPOWER
MAJOR MODEL CONFIGURATION CHANGES (REPRESENTATIVE EXAMPLES)	CONVERT 2-STROKE TO 4-STROKE
	LIQUID COOLING
	ADD HYDRAULIC TORQUE CONVERTER
	CONVERT TO SHAFT DRIVE
	ENCLOSE/COVER ENGINE

Table 7-2

ESTIMATED PERCENTAGE OF STREET MOTORCYCLES REQUIRING MAJOR MODEL CHANGES

REGULATORY LEVEL (SAE J331a not-to-exceed)	FRACTION OF MOTORCYCLE PRODUCTION REQUIRING MAJOR MODEL CHANGES	
	NOMINAL (EXPECTED) CASE	WORST CASE
86 dB	0%	0%
83 dB	0%	0%
80 dB	10%	50%
78 dB	50%	100%
75 dB	90%	100%

Table 7-3

ESTIMATED PERCENTAGES OF OFF-ROAD MOTORCYCLES REQUIRING MAJOR MODEL CHANGES

	Regulatory Level (A-weighted)	
Displacement Category (cc)	80 dB	78 dB
350 and above	100% (100%)	100% (100%)
170-349	50% (100%)	100% (100%)
100-169	0% (100%)	100% (100%)
99 and below	0% (0%)	0% (100%)
Overall (sales weighted)	10% (50%)	50% (100%)

Table 7-4

PROJECTED MOTORCYCLE TOTAL UNIT COST INCREASES FOR VARIOUS REGULATORY LEVELS (1978 dollars)

PRODUCT CLASSIFICATION	TOTAL UNIT COST INCREASE REGULATORY LEVEL (SAE J331a)				
	86 dB	83 dB	80 dB	78 dB	75 dB
NOMINAL (EXPECTED) CASE					
Street-Legal					
99 cc and Below	0	2	2	19	50
100 - 169 cc	0	6	18	74	148
170 - 349 cc	0	15	50	129	237
350 - 749 cc	0	19	56	152	287
750 cc and Above	0	22	71	175	321
Average street-legal	0	16	49	133	221
Off-Road					
99 cc and Below	0	2	2	19	*
100 - 169 cc	0	6	15	95	*
170 - 349 cc	6	20	76	155	*
350 - 749 cc	6	23	127	185	*
Average off-road	0	8	28	74	*
Fleet Average	0	14	43	117	*
WORST CASE					
Street-Legal					
99 cc and Below	0	2	2	19	50
100 - 169 cc	0	6	63	147	203
170 - 349 cc	0	15	96	180	246
350 - 749 cc	0	19	112	210	297
750 cc and Above	0	22	130	247	332
Average street-legal	0	16	99	192	223
Off-Road					
99 cc and Below	0	2	2	19	*
100 - 169 cc	0	6	62	147	*
170 - 349 cc	6	20	123	185	*
350 - 749 cc	6	23	151	214	*
Average off-road	2	18	50	94	*
Fleet Average	0	14	86	166	*

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* Information not available

The methodologies used to compute individual cost elements are similar with the exception of the testing/certification element. Generally, R&D, tooling, and testing/certification costs tend to be uniform for a given regulatory level for all motorcycle sizes. The manufacturing cost increases however, tend to become higher with increasing motorcycle size and are higher for off-road motorcycles than street types. Manufacturing costs account for between 60 percent and 70 percent of total unit cost.

7.1.1 Manufacturing Unit Costs

Manufacturing unit cost increases are those costs directly related to the use of noise control techniques that impact fabrication and assembly. As seen in Table 7-1, they generally relate to the exhaust, air-intake or mechanical-drive systems.

7.1.1.1 Manufacturer Estimates

Each major manufacturer supplied EPA with estimates of manufacturing unit cost increases for specific models to meet specified study levels (not-to-exceed standards). They made the major motorcycle model distinctions and their data were based on the SAE J331a test procedure.

Each manufacturer emphasized that most estimates at the lower levels were based on engineering judgment alone, and not on operational prototype models. They indicated that there was no guarantee that individual techniques cited would achieve the specified study level. Manufacturers addressed different ultimate levels of control depending on their assessment of feasibility or ability to judge the effectiveness of individual techniques. Manufacturer estimates are summarized in Figure 7-1.

Manufacturers also provided cost estimates for various discrete steps in reductions in exhaust, air-intake and mechanical/drive sources. Figures 7-2, 7-3 and 7-4 show costs associated with each of the subsources, where available.

Discussion of Data

There are a number of explanations for the scatter shown in Figure 7-1:

(a) In general, costs increase with motorcycle size, because noise generating capability tends to increase with size, and the costs of affected components (e.g., exhaust systems, mechanical components) increase with size.

(b) Since subsource noise level contributions differ widely from model to model (see Section 6) the techniques required to meet specified levels vary considerably.

(c) Since there are a wide variety of techniques which can be utilized in reducing the noise level from a given subsource, manufacturers projected differing techniques to be used, with attendant differences in costs.

(d) Major model changes were deemed necessary at different study levels. Data points denoted by an asterisk indicate the study level for which major model changes were assumed.

Costs associated with the reduction of exhaust system noise levels are shown in Figure 7-2. Again the large scatter in data indicates that for some exhaust systems, large reductions in noise levels are relatively inexpensive while others are considerably more expensive for the same degree of noise reduction. For example, for one model in the 350 to 749 cc category, a reduction in exhaust noise level (A-weighted) from 82 dB to 70 dB was projected by the manufacturer to increase manufacturing costs by $60. Almost all of the techniques listed for exhaust systems in Table 7-1 were used to achieve the reduction in this case.

Air intake noise reductions and associated cost increases are shown in Figure 7-3. There is less scatter in this data, although two of the models demonstrate wide variance. Most of the other data points fell on a curve with the following values:

Air Intake Noise Level	Associated Manufacturing Unit Cost Increase
84 dB	---
78 dB	$ 3.0
76 dB	$ 8.0
74 dB	$15.0
72 dB	$30.0

The estimated cost increases of mechanical/drive components versus degree of noise reduction are shown in Figure 7-4. The scatter here is due primarily to the use of major model changes and the study levels at which they were deemed to be necessary.

7.1.1.2 Generalized and Independent Estimates

The manufacturer-supplied data in the previous section referred to various specific motorcycle models and noise control techniques. These data were consolidated to obtain a generally applicable set of techniques at each study level and to assign a generally applicable cost estimate to each study level, for each class of motorcycle.

In addition, EPA's motorcycle technology contractor independently estimated the cost of individual techniques for comparison with the manufacturer-supplied data. This independent analysis was based on information gained in interviewing personnel familiar with the machining, costing, welding and other production processes involved. However, these estimates must be considered gross engineering judgments because of the difficulty in predicting the noise reducing effectiveness of the techniques involved. This same problem is encountered by motorcycle manufacturers and, in general, the independent estimates were in agreement with the data supplied by manufacturers. Consequently, these estimates were used in developing generalized estimates.

For exhaust and air intake modifications, a baseline was established for the cost elements of representative systems, and reasonable cost ranges were developed for each technique and its associated cost elements. Direct cost estimates were made for appropriate noise control techniques affecting

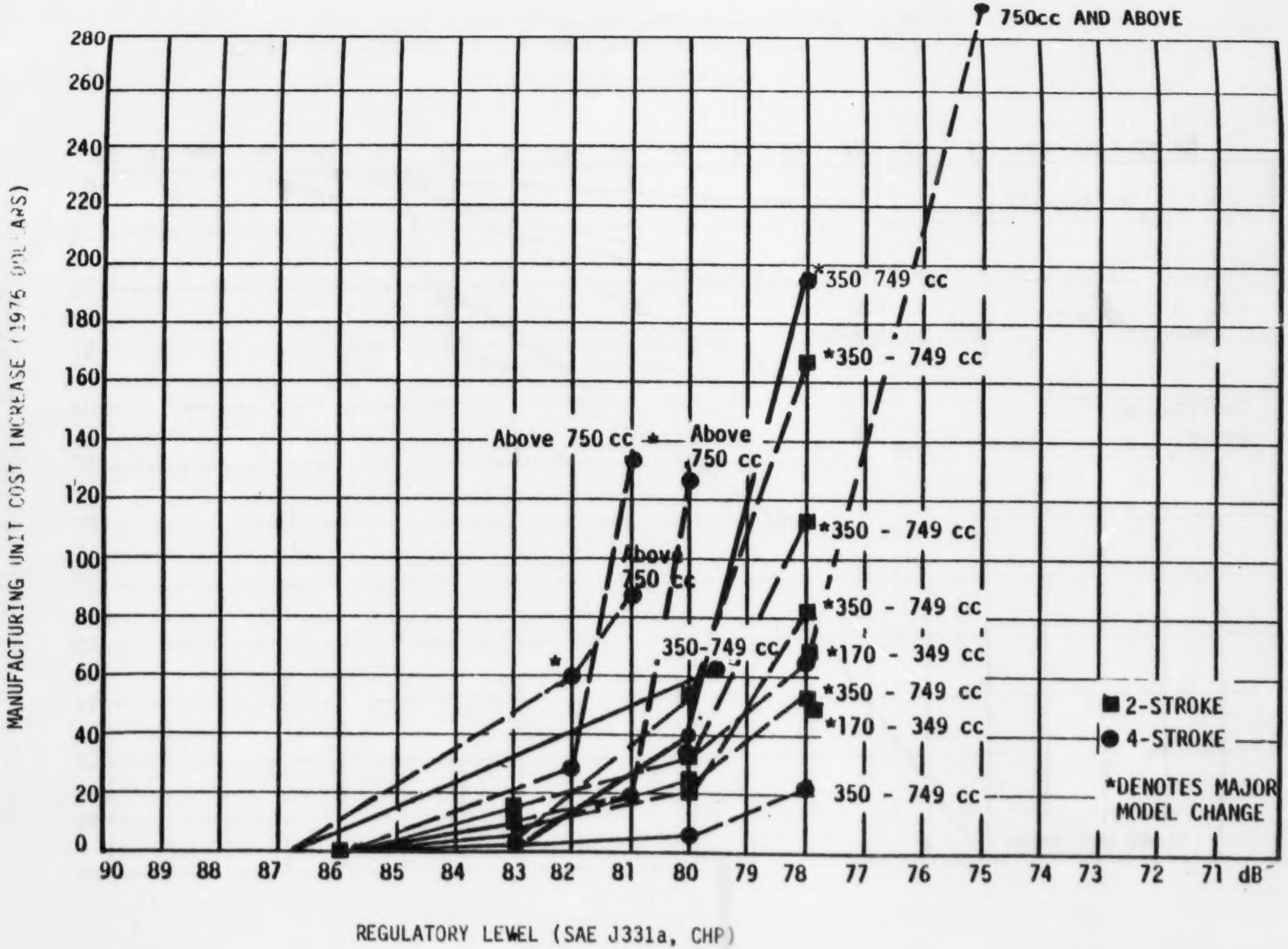

FIGURE 7-1 MANUFACTURING UNIT COST INCREASE VS. REGULATORY LEVEL (MANUFACTURER-SUPPLIED DATA)

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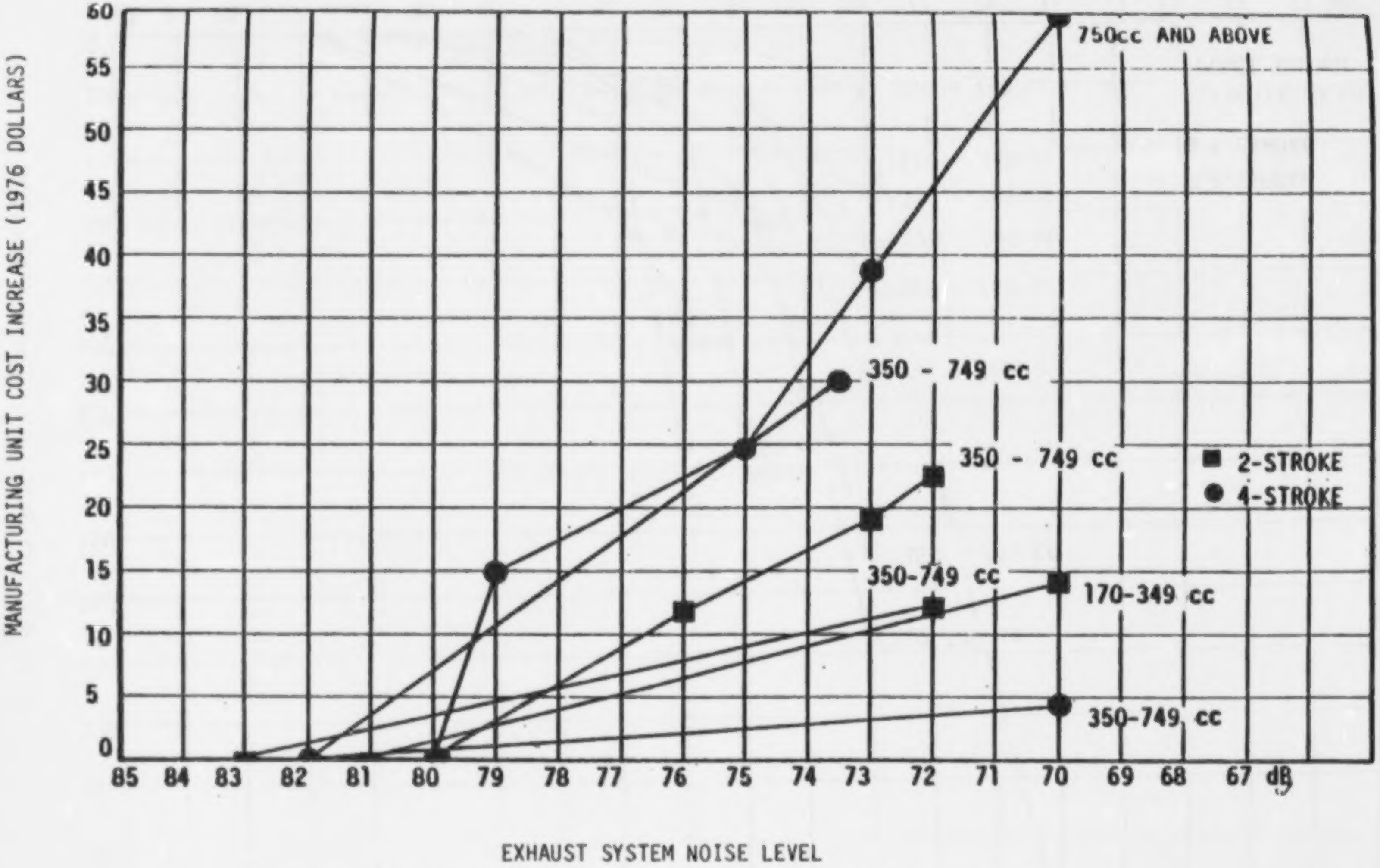

FIGURE 7-2 EXHAUST SYSTEM MANUFACTURING UNIT COST INCREASES VS. NOISE LEVEL REDUCTION (MANUFACTURER-SUPPLIED DATA)

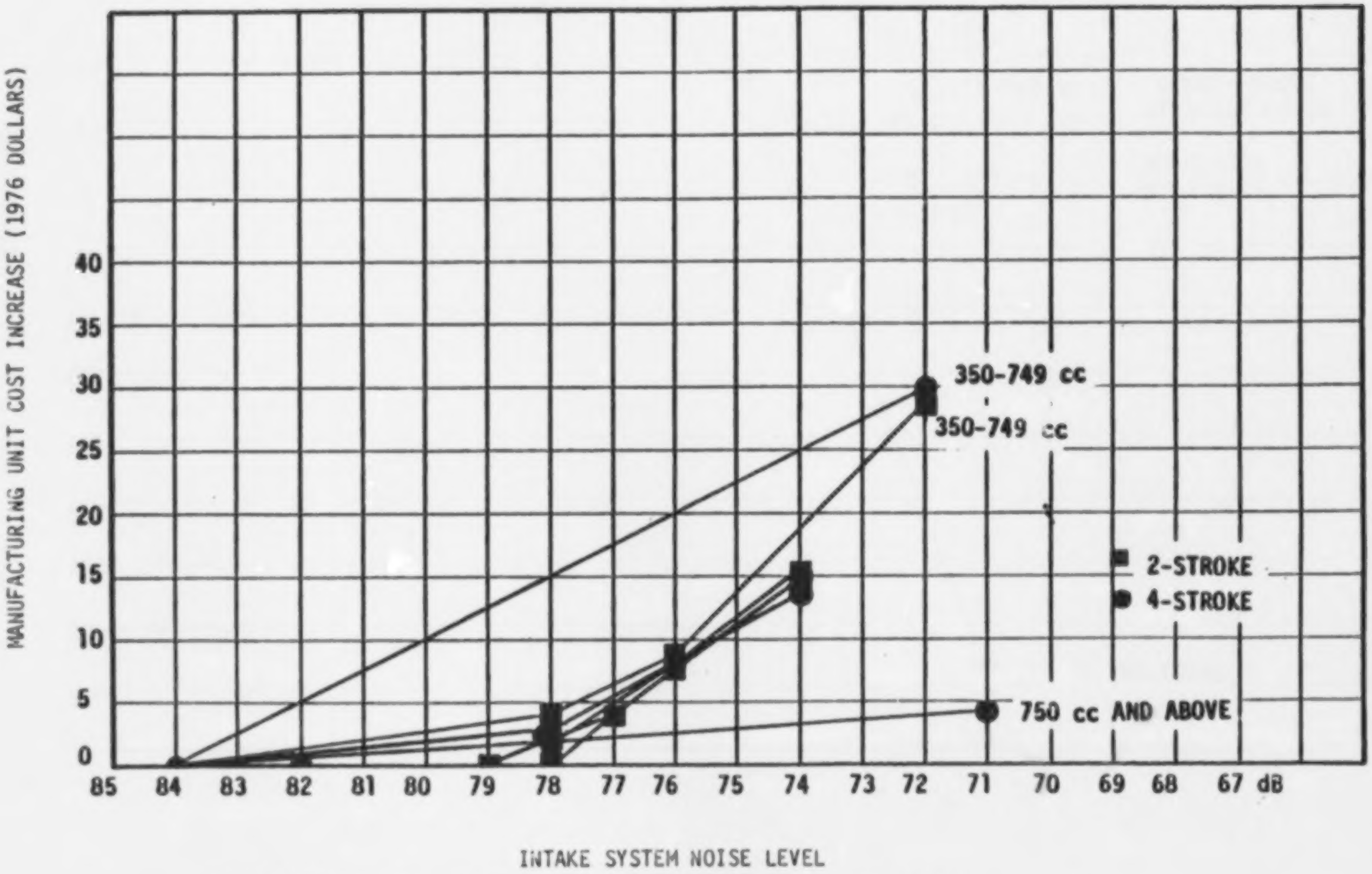

FIGURE 7-3 INTAKE SYSTEM MANUFACTURING UNIT COST INCREASE VS. NOISE LEVEL REDUCTION (MANUFACTURER-SUPPLIED DATA)

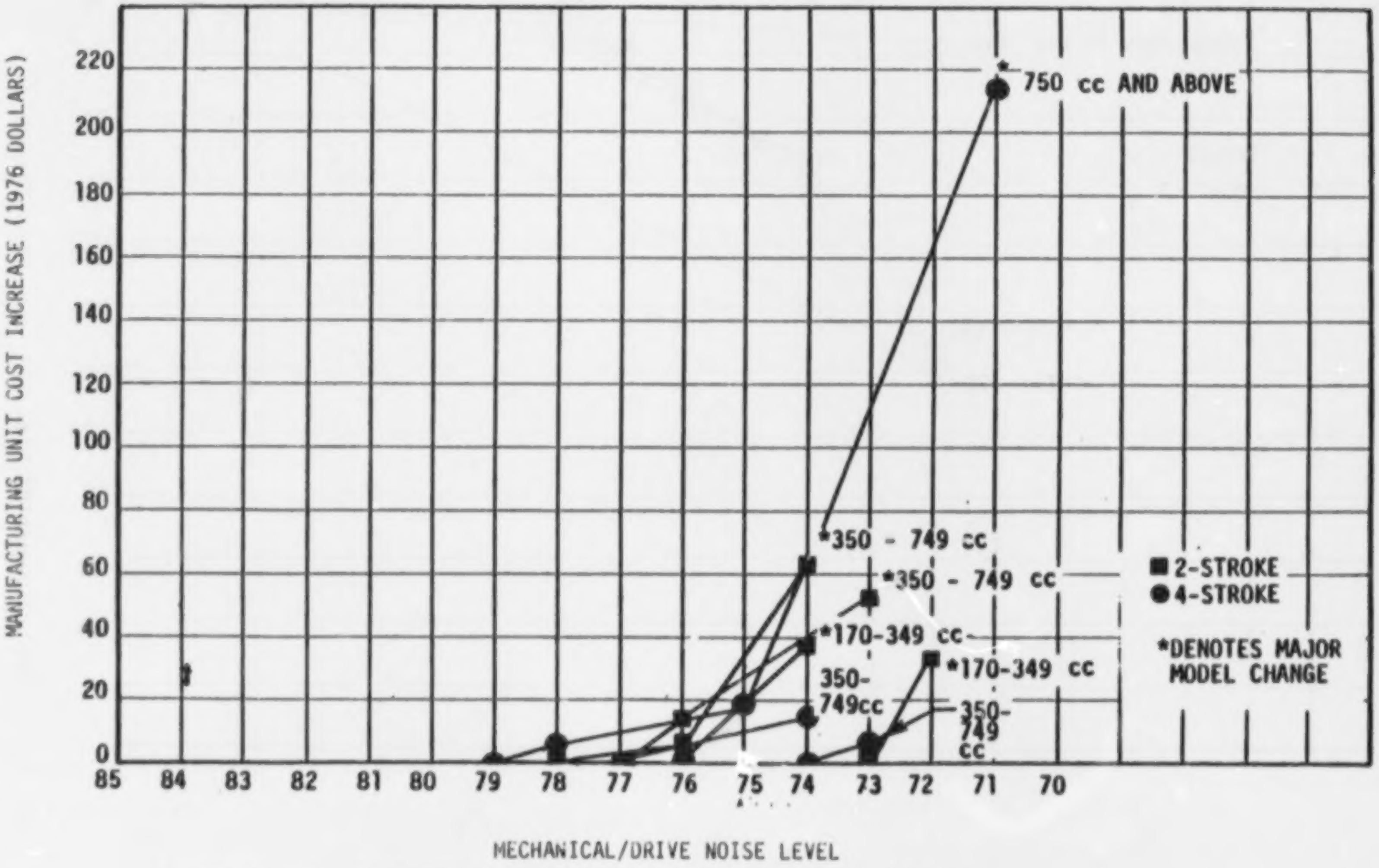

FIGURE 7-4 MECHANICAL/DRIVE MANUFACTURING UNIT COST INCREASE VS. NOISE LEVEL REDUCTION (MANUFACTURER-SUPPLIED DATA)

mechanical/drive components. Independent cost estimates for exhaust system, air-intake system and mechanical drive system techniques are summarized in Tables 6, 7 and 8 respectively.

In the case of major model changes, the use of liquid cooling was assumed for street motorcycles. Liquid cooling may not necessarily be the major change that is used in all cases, but it is felt that its cost is representative of the magnitude of costs major model changes will incur. A rough order of magnitude cost estimate for the addition of liquid cooling to a street motorcycle in the 750 cc and above category is provided below in Table 7-5.

Table 7-5

LIQUID COOLING: Street Motorcycle, 750 cc and Above
(rough order cost approximation)

ITEM	COST
Sheet Metal Material	$10
Radiator	10
Plumbing	2
Pump	7
Miscellaneous Hardware	4
Fabrication Labor*	47
Total	$80

The basic cost elements were selected and scaled according to their estimated relationships with motorcycle size, relative effectiveness of the techniques, and the degree of noise attenuation required. An example of the technique used is shown in Table 7-9 using 1975 dollars. This procedure was followed for each motorcycle category, regulatory design levels, and for both straight-forward and major model changes as applicable.

The independent estimates of manufacturing unit cost increases attributable to meeting not-to-exceed regulatory levels for all specific product categories are summarized in Table 7-10.

These estimates were derived by using the methodology described in the previous section. The analysis utilized the assumptions shown in Table 6-2 for the technology required at each study level.

In the case of major model changes, the use of liquid cooling was assumed for street motorcycles. Conversion to 4-stroke engines was assumed for pure off-road motorcycles meeting noise emission standards more stringent than 82 dB, at the same cost (up to $80 depending on engine size).

In the independent cost estimate very small differences were predicted in cost impacts between motorcycles with 2-stroke and 4-stroke engines,

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* Includes welding machining, and assembly.

Table 7-6

EXHAUST SYSTEM NOISE REDUCTION TECHNIQUES AND ESTIMATED COSTS
(INDEPENDENT ESTIMATES)

TECHNIQUE	SPECIAL APPLICABILITY	AFFECTED COMPONENTS AND COST ELEMENTS	MANUFACTURERS UNIT COST INCREASES (1978 DOLLARS) UNDER 100 cc	100-169 cc	170-349 cc	350-749 cc	750-Above	COST VARIABILITY FACTORS	COMMENTS
INCREASE MUFFLER VOLUME		MUFFLER SHELLS & FINISH (CHROME, PAINT	1-2	1-3	1-4	1-5	1-6	DEGREE OF VOLUME INCREASE PRODUCT CLASS	GENERALLY PRACTICAL LIMIT - 100% INCREASE
INSTALL CROSS-PIPES BETWEEN HEADERS	DUAL EXHAUST SYSTEM ONLY	HEADERS CROSS PIPES	N/A	N/A	N/A	10	12		LABOR INTENSIVE
MODIFY HEADER INTERCONNECTIONS	MULTI-CYLINDER	HEADER PIPES	N/A	N/A	N/A				LABOR INTENSIVE
(COLLECTIVE MUFFLERS)	MOTORCYCLES ONLY	COLLECTION BOXES							
4 into 1						14	14		
4 into 2						14	14		
3 into 1						11	11		
2 into 1						7	7		
MODIFY INTERIOR		ASSEMBLY CORE PIPES BAFFLES REACTIVE CHAMBERS	1-4	1-8	1-12	1-14	1-16	DEGREE OF MODIFICATION PRODUCT CLASSIFICATIONS	GENERALLY IDLE COMPLEX ASSEMBLY
ADD SOUND ABSORPTION LINING		LINING MAT'L LINING HOLDERS, SCREENS, ETC.	1-3	1-3	1-4	1-5	1-7	TYPE OF LINING MATERIAL COMPLEXITY OF INSTALLATION	
THICKEN/REINFORCE SHELL MATERIAL		MUFFLER SHELL REINFORCEMENT HARDWARE		1-8	1-10	1-12	1-14	DEGREE OF THICKNESS INCREASE DEGREE OF VOLUME	

Table 7-7

AIR INTAKE SYSTEM NOISE AND REDUCTION TECHNIQUES AND ESTIMATED COSTS
(INDEPENDENT ESTIMATES)

TECHNIQUE	AFFECTED COMPONENTS AND COST ELEMENTS	MANUFACTURERS UNIT COST INCREASES (1975 DOLLARS)					COST VARIABILITY FACTORS
		UNDER 100cc	100-169cc	170-349cc	350-749cc	750-Above	
INCREASE VOULME	INLET DUCTING AIR CLEANER BODY	1-2	1-2	1-2	1-3	1-3	DECREASE OF VOLUME INCREASE PRODUCT CLASS
MODIFY INTAKE INLET	INLET DUCTING	1-3	1-3	1-6	1-6	1-7	DEGREE OF MODIFICATION PRODUCT CLASS
MODIFY INTERIOR	ASSEMBLY BAFFLES SILENCERS	1-5	1-5	1-6	1-6	1-10	
ADD SOUND ABSORPTION LINING		-	1	1-2	1-2	1-3	
INCREASE MATERIAL THICKNESS	AIR CLEANER BODY	-	1-3	1-4	1-6	1-7	
CONSTRUCT DOUBLE WALLS	AIR CLEANER BODY	-	-	-	-	-	NOT USED IN COST ANALYSIS
SHIELD INLET	INLET OPENING	-	-	-	-	-	NO COST IMPACT
REDUCE INLET AREA	INLET OPENING	-	-	-	-	-	NO COST IMPACT

Table 7-8

MECHANICAL NOISE REDUCTION TECHNIQUES AND APPROXIMATE COSTS
(INDEPENDENT ESTIMATES)

TECHNIQUE	APPLICATION	APPROXIMATE MANUFACTURING UNIT COST INCREASE (1975 DOLLARS)					COST VARIABILITY FACTORS	COMMENTS
		UNDER 100 cc	100-169 cc	170-349 cc	350-749 cc	750-Above		
STIFFER FINS AND CASE WEBS	RUBBER OR METAL DOWELL BETWEEN FINS	1	1	1	1	1		
CHANGE FIN SHAPES	MODIFY DESIGN	-	-	-	-	-		NO COST IMPACT
ISOLATE/REINFORCE COMPONENTS	ADD GASKETS, BURNINGS, ETC.	-	2	2	2	2		
THICKEN/REINFORCE CASE COVERS	MODIFY ENGINE, GEAR, CRANKCASE COVERS		1-6	1-10	1-4	1-15	NO.OF COVERS DEGREE OF MODIFICATION	
INCREASE LUBRICATION	INCREASE PRESSURE LUBRICATION	-	2	2	2	2		
MODIFY PISTON/CYLINDER	MODIFY PISTON/CYLINDER DESIGN AND CLEARANCE	1	1	1	1	1		
REDUCE TOLERANCES/IMPROVE FINISH	REDUCE TOLERANCES, IMPROVE FINISH OF MACHINED PARTS	-	1-2	1-2	1-3	1-3		
MODIFY BEARINGS	MODIFY BEARING AREA, MATERIAL		2	2	2	2		
MODIFY ENGINE TIMING AND DRIVE BELTS/CHAINS	CONVERT FROM CHAIN DRIVE TO HT-YD OR OTHER TYPE		4	5	6	6		
REDUCE VALVE CLATTER	USE HYDRAULIC LIFTERS ON 4-STROKE ENGINES	-	-	-	-	-	NOT USED IN COST ANALYSIS	
INCREASE FLYWHEEL MASS	CRANKSHAFT FLYWHEEL	1	1	1	1	1		
MODIFY CRANKSHAFT/CANSHAFT	MODIFY CRANKSHAFT DESIGN	-	-	-	-	-		GENERALLY NO COST
MODIFY CLUTCH		-	-	-	-	-	NOT USED IN COST ANALYSIS	TECHNICAL EFFECTIVENESS
MODIFY GEAR/TRANSMISSION	USE OF HELICAL GEARS INSTEAD OF SPUR GEARS	-	5	8	9	10		
TIGHTEN DRIVE CHAIN	INSTALL, MODIFY IDLER ARMS	-	-	-	-	-	NOT USED IN COST ANALYSIS	SHOULD HAVE MINIMAL COST IMPACT
ENCLOSE DRIVE CHAIN	INSTALL STEEL CASE	-	6	9	10	11		
MODIFY FRAME	REDESIGN, INSULATE FRAME	-	-	-	2	2		

BECAUSE OF SPECIAL APPLICABILITY

Table 7-9

MANUFACTURING COST INCREASE ESTIMATES (1975 DOLLARS)

SIZE: 170 - 349 cc

CHANGE CATEGORY: STRAIGHT FORWARD MODEL CHANGE

NOISE CONTROL TECHNIQUE		COST	
OVERALL NOISE LEVEL (dB)	86-83 dB	80 dB	78 dB
EXHAUST	75 dB	73 dB	70 dB
Increase muffler volume	1.0	2.0	3.0
Install cross pipes between mufflers			
Modify header interconnections			
Modify interior core	1.0	2.0	5.0
Add sound absorption lining		1.0	2.0
Increase shell material thickness			3.0
Construct double walls			
Add elastic components			
SUBTOTAL	$2.0	$6.0	$13.0
AIR INTAKE (dB)	75 dB	73 dB	70 dB
Increase volume	1.0	1.0	2.0
Modify intake inlet		1.0	2.0
Modify interior core	1.0	1.0	2.0
Add sound absorption lining		1.0	1.0
Increase material thickness		1.0	2.0
Construct double walls			
Shield inlet			
Add/modify plenum chambers			
SUBTOTAL	$2.0	$5.0	$9.0
MECHANICAL (dB)			
Stiffen fins and case webs		1.0	1.0
Change fin shapes			
Isolate/reinforce components		2.0	2.0
Thicken/reinforce case covers		3.0	5.0
Increase lubrication			2.0
Modify piston/cylinder			1.0
Reduce tolerances/improve finish			2.0
Modify bearings			2.0
Modify timing belt/camshaft			
Reduce valve clatter (4-stroke)			
Enlarge flywheel			1.0
Modify crankshaft			
Modify (damp) clutch			
Modify gear/transmission			
Tighten drive chain			
Enclose drive chain			
Modify frame			
MAJOR MODEL CHANGES:			
Convert 2-stroke to 4-stroke			
Use liquid cooling			
Enclose/cover engine			
Add hydraulic torque converter			
Convert to shaft drive			
Reduce engine RPM			
SUBTOTAL		$6.0	$16.0
TOTAL MANUFACTURING COST INCREASE	$4.0	$16.0	$38.0

Table 7-10

MANUFACTURING UNIT COST INCREASES VERSUS REGULATORY LEVELS - BASELINE INDEPENDENT ESTIMATE (1978 DOLLARS)

	MANUFACTURING UNIT COST INCREASE REGULATORY LEVEL (SAE J331a)				
PRODUCT CLASSIFICATION	86 dB	83 dB	80 dB	78 dB	75 dB
STRAIGHT FORWARD "CHANGES"					
Street-Legal					
99 cc and Below	0	0	0	0	0
100-169 cc	0	3	9	30	72
170-349 cc	0	5	19	44	108
350-749 cc	0	9	23	61	144
750 cc and Above	0	12	35	72	167
Off-Road					
99 cc and Below	0	0	0	9	*
100-169 cc	0	3	10	30	*
170-349 cc	5	10	23	49	*
350-749 cc	5	13	29	66	*
MAJOR MODEL CHANGES					
Street-Legal					
100-169 cc	*	*	53	74	105
170-349 cc	*	*	64	88	140
340-749 cc	*	*	93	118	191
750 cc and Above	*	*	119	155	226
Off-Road					
100-169 cc	*	*	57	74	*
170-349 cc	*	*	71	93	*
350-749 cc	*	*	99	122	*

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* Information not available

with the exception of those cases requiring 2-stroke to 4-stroke conversion. As a result, except for the conversion costs (off-road models), 2-stroke and 4-stroke cost impacts were considered equivalent in the independent cost analysis. Note also that no major model changes were forecasted for motorcycles under 100 cc in size, for the following reasons: (1) none of the manufacturers indicated that models in this category would require major redesign to meet specified regulatory levels; and (2) the existing noise levels of motorcycles in this category are relatively low.

A breakdown of baseline independent cost estimates in terms of exhaust, air-intake, and mechanical components is shown in Table 7-11 using 1975 dollars.

These numbers were then modified for nominal and worst cases by the estimated percentage of major model changes required for each regulatory level (refer to Table 7-12). The resultant costs were included in the projected total unit cost increase (refer to Table 7-4), although they were adjusted to 1978 dollars based on average price increases for motorcycles between these years.

7.1.2 Research and Development Costs

Total unit cost increases listed in Table 7-4 include R&D costs incurred in order to comply with noise standards.

Research and development costs include the cost of: R&D personnel, laboratory facilities and diagnostic equipment, prototype motorcycles, materials and components, and production design and drawings. The impact of research and development costs on unit cost is particularly difficult to determine because of variances in the sizes and characteristics of the companies involved; the differences in depth and breadth of each company's product line; extent of expenditures in the effort that can be considered "sunk" costs and have already been amortized; unknown technical complexities and model peculiarities that will be encountered in the R&D and production design program; differences in available resources and personnel; and differences in cost accounting policies.

Impacts will also depend on program variables. For example, the degree of noise reduction required for each class of motorcycle will determine whether "straight-forward" or major model changes are required to comply with regulatory levels. Estimates for unit cost increases attributable to amortized R&D for these two types of changes were supplied by manufacturers. These data were assessed for reasonableness, and used to derive unit cost increases. Again, these estimates were modified by the probabilities associated with straight-forward and major model changes in the nominal and worst cases.

The generalized estimates in Table 7-13 for Category I manufacturers (manufacturers that produce 100,000 units or more annually) were modified by two factors to derive the composite (weighted) average R&D unit cost increases for all manufacturers, shown in Table 7-14. The two factors considered are: (1) approximately 86% of all motorcycles sold in the U.S. are manufactured by Category I manufacturers, and (2) R&D unit costs for Category

Table 7-11

MANUFACTURING UNIT COST INCREASES VERSUS REGULATORY LEVELS - BASELINE INDEPENDENT ESTIMATE (1975 DOLLARS)

SIZE CATEG. (cc)	MODEL DESCRIPTION FUNCTION	TEST PROC.		REGULATORY LEVELS* (dB)				MANUFACTURING COST INCREASE				CHANGE** CLASS.
			0	0	EX	IU	M/D	OVER-ALL (O)	EX-HAUST (EX)	AIR INTAKE (IN)	MECH/ DRIVE (M/D)	
750 and Above	Street-Legal	SAE J331a	86	83	75	75	75	10	6	4	0	SFMC
				80	72	72	73	30	13	10	7	
				78	70	70	71	63	24	16	23	
				75	67	67	68	146	52	30	64	
350-749	Street-Legal	SAE J331a	86	83	75	75	75	8	4	4	0	SFMC
				80	72	72	73	22	9	6	7	
				78	70	70	71	55	18	12	25	
				75	67	67	68	129	44	25	60	
170-349	Street-Legal	SAE J331a	86	83	75	75	75	4	2	2	0	SFMC
				80	72	72	73	16	5	5	6	
				78	70	70	71	38	13	9	16	
				75	67	67	68	92	27	20	45	
100-169	Street-Legal	SAE J331a	86	83	75	75	75	2	1	1		SFMC
				80	72	72	73	8	3	4	1	
				78	70	70	71	25	11	8	6	
				75	67	67	68	61	20	14	27	
99 and Below	Street-Legal	SAE J331a	86	78	71	71	69	7	3	4	0	SFMC
				75	67	67	69	17	9	8	0	

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* Regulatory not-to-exceed noise level applicable to overall (0) level. Subsources are design level.

** SFMC - Straight Forward Model Change.
MMD - Major Model Change

Table 7-11 (continued)

MANUFACTURING UNIT COST INCREASES VERSUS REGULATORY LEVELS - BASELINE INDEPENDENT ESTIMATE (1975 DOLLARS)

SIZE CATEG. (cc)	MODEL DESCRIPTION FUNCTION	TEST PROC.	0	REGULATORY LEVELS* (dB)				MANUFACTURING COST INCREASE				CHANGE** CLASS.
				0	EX	IU	M/D	OVER-ALL (0)	EX-HAUST (EX)	AIR INTAKE (IN)	MECH/ DRIVE (M/D)	
350-749	Off-Road	SAE J331a	89	86	82	82	75	4	2	2	0	SFMC
				83	75	75	75	12	6	6	0	
				80	72	72	73	26	11	8	7	
				78	70	70	71	59	20	14	25	
170-349	Off-Road	SAE J331a	89	86	82	82	75	4	2	2	0	SFMC
				83	75	75	75	8	4	4	0	
				80	72	72	73	20	7	7	6	
				78	70	70	71	42	15	11	16	
100-169	Off-Road	SAE J331a	86	83	75	75	75	2	1	1	0	SFMC
				80	72	72	73	8	3	4	1	
				78	70	70	71	25	11	8	6	
99 and Below	Off-Road		80	78	71	71	69	7	3	4	0	SFMC
				75	67	67	69	17	9	8	0	

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* Regulatory not-to-exceed noise level applicable to overall (0) level. Subsources are design level.

** SFMC - Straight Forward Model Change.
MMD - Major Model Change

Table 7-11 (Continued)

MANUFACTURING UNIT COST INCREASES VERSUS REGULATORY LEVELS - BASELINE INDEPENDENT ESTIMATE (1975 dollars)

SIZE CATEG. (cc)	MODEL DESCRIPTION FUNCTION	TEST. PROC.	REGULATORY LEVELS* (DB)					MANUFACTURING COST INCREASE				CHANGE** CLASS.
			O	O	EX	IU	M/D	OVER-ALL (O)	EX-HAUST (EX)	AIR INTAKE (IN)	MECH/ DRIVE (M/D)	
750 and Above	Street-Legal	SAE J331a	86	83	75	75	75	10	6	4	0	MMC
				80	72	72	73	103	13	10	80	@
				78	70	70	71	135	24	16	95	80
				75	67	67	68	190	52	30	116	dB
350-749	Street-Legal		86	83	75	75	75	8	4	4	0	MMC
				80	72	72	73	85	9	6	70	@
				78	70	70	71	108	18	12	78	80
				75	67	67	68	174	44	25	105	dB
170-349	Street-Legal	SAE J331a	86	83	75	75	75	4	2	2	0	MMC
				80	72	72	73	55	5	5	45	@
				78	70	70	71	74	13	9	52	80
				75	67	67	68	118	27	20	71	dB
100-169	Street-Legal	SAE J331a	86	83	75	75	75	2	1	1	0	MMC
				80	72	72	73	47	3	4	40	@
				78	70	70	71	61	11	8	42	80
				75	67	67	68	87	20	14	53	dB

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* Regulatory not-to-exceed noise level applicable to overall (O) level. Subsources are design level.

** SFMC - Straight Forward Model Change.
MMD - Major Model Change

Table 7-11 (Continued)

MANUFACTURING UNIT COST INCREASES VERSUS REGULATORY LEVELS -
BASELINE INDEPENDENT ESTIMATE (1975 dollars)

SIZE CATEG. (cc)	MODEL DESCRIPTION FUNCTION	TEST. PROC.	REGULATORY LEVELS* (dB)					MANUFACTURING COST INCREASE				CHANGE** CLASS.
			0	0	EX	IU	M/D	OVER-ALL (0)	EX-HAUST (EX)	AIR INTAKE (IN)	MECH/ DRIVE (M/D)	
350-749	Off-Road	SAE J331a	89	86	82	82	75	4	2	2	0	MMC
				83	75	75	75	12	6	6	0	
				80	72	72	73	89	11	8	70	80
				78	67	70	71	112	20	14	78	dB
170-349	Off-Road	SAE J331a	89	86	82	82	75	4	2	2	0	SFMC
				83	75	75	75	8	4	4	0	
				80	72	72	73	59	7	7	45	80
				78	67	70	71	78	15	11	52	dB
100-169	Off-Road	SAE J331a	86	83	75	75	75	2	1	1	0	SFMC
				80	72	72	73	47	3	4	40	
				78	70	70	71	61	11	8	42	80 dB

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* Regulatory not-to-exceed noise level applicable to overall (0) level. Subsources are design level.

** SFMC - Straight Forward Model Change.
MMD - Major Model Change

Table 7-12

MANUFACTURING UNIT COST INCREASES FOR VARIOUS REGULATORY LEVELS NOMINAL AND WORST CASES (1978 Dollars)

PRODUCT CLASSIFICATION	MANUFACTURING UNIT COST INCREASE REGULATORY LEVEL (SAE J331a)				
	86 dB	83 dB	80 dB	78 dB	75dB
NOMINAL (EXPECTED) CASE					
Street-Legal					
99 cc and Below	0	0	0	9	21
100 - 169cc	0	3	13	52	100
170 - 349cc	0	5	23	67	136
350 - 749cc	0	9	29	90	186
750 cc and Above	0	12	44	113	220
Off-Road					
99 cc and Below	0	0	0	9	*
100 - 169 cc	0	3	10	73	*
170 - 349 cc	5	10	49	93	*
350 - 749 cc	5	13	100	123	*
WORST CASE					
Street-Legal					
99 cc and Below	0	0	0	9	21
100 - 169 cc	0	3	35	74	105
170 - 349 cc	0	5	44	88	140
350 - 749 cc	0	9	60	118	191
750 cc and Above	0	12	78	155	226
Off-Road					
99 cc and Below	0	0	0	9	*
100 - 169 cc	0	3	57	74	*
170 - 349 cc	5	10	71	93	*
350 - 749 cc	5	13	99	122	*

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* Information not available

II manufacturers (manufacturers that produce less than 100,000 units per year) are estimated to be double those of Category I manufacturers.

The second factor is to be expected because total R&D expenses are allocated over fewer units when estimating costs on a per unit basis. Therefore the composite weighted average for all motorcycle manufacturers should be roughly 1.14 times the cost of Category I manufacturers.

Table 7-15 shows nominal and worst case R&D unit costs associated with different regulatory levels. These values are used in computing total unit cost increases.

7.1.3 Tooling and Other Manufacturing Equipment Costs

Total unit cost increases in Table 7-4 also include expenditures related to addition or modification of tooling and other production related equipment.

Generalized cost estimates for Category I manufacturers are summarized in Table 7-16. Estimates for both straightforward and major model changes are provided. The generalized estimates represent an evaluation of trends indicated in manufacturer-supplied data. A liberal (high) estimate of unit tooling costs for major model changes was used.

Tooling costs on a unit basis tend to be considerably higher for Category II manufacturers (producing 100,000 units per year or less), because fixed expenses are allocated over fewer units. As in the case of R&D expenses, it would appear that unit tooling costs for Category II manufacturers are approximately double that of Category I manufacturers.

A composite weighted average for all manufacturers was computed using the 1.14 factor derived for R&D costs. The weighted average is summarized in Table 7-17. Composite cost estimates for nominal and worst cases are summarized in Table 7-18.

These costs are included in the total unit cost increases listed in Table 7-4.

7.1.4 Testing and Certification Costs

For standardized acceleration tests, the basic sound level meter and accessories required typically cost between $550 and $2,600 in 1975 dollars (See Table 7-19). A sound level recorder, if necessary, would cost an additional $2,400.

(a) Moving Tests

The test facilities of major vehicle manufacturers are generally permanent installations, and cost at least $225,000 and up. A common alternative to setting up permanent facilities is to lease test sites. A typical facility rental cost would be $100 per day. Based on experience gained in

Table 7-13

MOTORCYCLE UNIT COST INCREASES GENERALIZED COST ESTIMATE DUE TO R&D EXPENSES: CATEGORY I MOTORCYCLES MANUFACTURERS (1978 DOLLARS)

TYPE OF CHANGE	MOTORCYCLE UNIT COST INCREASE REGULATORY LEVEL (SAE J331a) 86 dB	83 dB	80 dB	78 dB	75 dB
Straightforward Model Change	$1	$2	$9	$16	$24
Major Model Change @ 80 dB (SAE J331a)	*	*	$37	$41	$49

Table 7-14

MOTORCYCLE UNIT COST INCREASE DUE TO AMORTIZED R&D EXPENSES: COMPOSITE WEIGHTED AVERAGE FOR ALL MANUFACTURERS (1978 DOLLARS)

TYPE OF CHANGE	MOTORCYCLE UNIT COST INCREASE REGULATORY LEVEL (SAE J331a) 86 dB	83 dB	80 dB	78 dB	75 dB
Straightforward Model Change	$1	$2	$10	$19	$28
Major Model Change @ 80 dB (SAE J331a)	*	*	$42	$46	$56

Derivation Notes:

1. Available information indicates that manufacturers with production volumes less than 100,000 units per year are likely to have unit R&D costs that are twice (2) that of manufacturers with production volumes of 100,000 or more units per year.

2. Manufacturers with production volumes less than 100,000 units per year sell 14% of all motorcycles sold in the U.S.

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*Information not available

Table 7-15

MOTORCYCLE UNIT COST INCREASES DUE TO AMORTIZED R&D EXPENSES; NOMINAL (EXPECTED) AND WORST CASES (1978 DOLLARS)

	MOTORCYCLE UNIT COST INCREASE REGULATORY LEVEL (SAE J331a)				
	86 dB	83 dB	80 dB	78 dB	75 dB
Nominal (Expected) Case	$1	$2	$13	$33	$53
Worst Case	$1	$2	$26	$46	$55

Table 7-16

MOTORCYCLE UNIT COST INCREASES GENERALIZED COST ESTIMATE DUE TO TOOLING EXPENSES FOR CATEGORY I MOTORCYCLES MANUFACTURERS (1978 DOLLARS)

TYPE OF CHANGE	MOTORCYCLE UNIT COST INCREASE REGULATORY LEVEL (SAE J331a)				
	86 dB	83 dB	80 dB	78 dB	75 dB
Straightforward Model Change	$0	$5	$8	$10	$15
Major Model Change @ 80 dB (SAE J331a)	*	*	$35	$38	$43

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* Information not available

Table 7-17

MOTORCYCLE UNIT COST INCREASES DUE TO TOOLING EXPENSES: COMPOSITE WEIGHTED AVERAGE FOR ALL MANUFACTURERS (1978 DOLLARS)

TYPE OF CHANGE	MOTORCYCLE UNIT COST INCREASE REGULATORY LEVEL (SAE J331a)				
	86 dB	83 dB	80 dB	78 dB	75 dB
Straightforward Model Change	$0	$6	$9	$12	$17
Major Model Change @ 80 dB (SAE J331a)	*	*	$40	$44	$49

Table 7-18

MOTORCYCLE UNIT COST INCREASES DUE TO TOOLING EXPENSES: NOMINAL (EXPECTED) AND WORST CASES (1978 DOLLARS)

	MOTORCYCLE UNIT COST INCREASE REGULATORY LEVEL (SAE J331a)				
	86 dB	83 dB	80 dB	78 dB	75 dB
Nominal (Expected) Case	$0	$6	$12	$27	$46
Worst Case	$0	$6	$24	$44	$49

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* Information not available

Table 7-19

TYPICAL COST OF SOUND LEVEL METERS AND ACCESSORIES

COMPONENT	COST
Type I Sound Level Meter (B&K 2209)	$1,706
Microphone	343
Pistonphone	475
Accessories (tripod, windscreen, etc.)	100
	$2,624
Type II Sound Level Meter (B&K 2213)	$ 354
Acoustic Calibrator	177
Accessories	15
	$ 546
Sound Level Recorder (B&K 2306)	$2,400

Source: B&K Catalog (prices as of July 1, 1975).

EPA's motorcycle test program, the noise levels of approximately 20 motorcycles can be measured per eight-hour period, since the initial set-up time is minimal. The tests require two technicians and a rider, and include six noise level measurements in each direction.

For an aftermarket exhaust system manufacturer, considerably more time would be required to transport motorcycles to leased test facilities, to set-up the test site, and to exchange exhaust systems as required. Again, based on EPA's test experience, the noise levels of approximately eight exhaust system configurations can be measured in an eight-hour period. These costs are delineated in Tables 7-20 A, B, C, D, E, F.

(b) Stationary Tests

Stationary tests are the simplest tests to administer and require minimal facilities. In addition, the actual testing time is almost negligible. The two basic elements for estimating testing costs are the measurement rates and the number of personnel required. Costs can be computed by using an appropriate labor rate combined with the number of tests conducted.

Estimated testing costs for three motorcycle manufacturers are summarized in Table 7-20. An EPA estimate appears in Table 7-21.

Although EPA estimates of test and administration costs are considerably lower, manufacturer estimates were used in computing unit cost increases for testing and compliance requirements. For major manufacturers, unit costs were figured on the basis of 270,000 unit sales per year, with equipment amortization over a four-year period. A breakdown of the manufacturer estimated costs using 1978 dollars follow:

Cost Element	Cost	Cost on Annual Basis	Unit Cost
Equipment	$350,000	$ 87,500	0.32
Test and Administration Cost	$350,000	350,000	1.30
		Subtotal	1.62

Assuming that unit costs for smaller manufacturers are higher, a reasonable estimate for the composite weighted average for all motorcycles is $1.75 per unit. In addition, Harley Davidson estimates labeling would add approximately $0.5 to unit costs.[1] Compliance testing and certification costs would therefore add approximately $2.25/unit costs, and this value is included in total unit cost increases (refer to Table 7-4).

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[1] AMF/Harley-Davidson's reply to Exhaust Emission Notice of Proposed Rulemaking, January 30, 1976

Table 7-20 A

ASSUMPTIONS USED TO DESCRIBE A LARGE AFTERMARKET MANUFACTURER AND A SMALL AFTERMARKET MANUFACTURER

Item	Large Manufacturer	Small Manufacturer
Revenue from exhaust systems	1,000K	200K
No. of exhaust system models	126	25
No. of different muffler cores	13	4
No. of cores requiring R&D at the 83/86 dB level	5	2
No. of cores requiring R&D at the 80/82 dB level	10	4
No. of new motorcycles added to product line coverage each year	5	2
No. of current year motorcycles for which exhaust systems are offered	30	12
Cumulative percentage of revenues from mufflers for regulated motorcycles		
in 1st year:	16%	16%
in 2nd year:	32%	32%
in 3rd year:	48%	48%

Table 7-20 B

EXHAUST SYSTEM MANUFACTURER'S, COSTS FOR R&D BY THE FEDERAL PASS-BY TEST AND BY THE F50 STATIONARY TEST

Item	Federal Pass-by Test	Stationary F50 Test
Cost of Redesign of 10 muffler cores:*		
Labor	$15,500	$11,800
Site	1,300	--
Motorcycle costs	900	900
Transportation	1,300	--
Test equipment	300	300
	$19,300	$13,000
	or about $1900/core	or about $1300/core

*Labor for Pass-by Test: one engineer for 3 months @ $20/hr = $10,400; one day of testing per week for 3 months = 13 days; 2 technicians @ $12/hr plus one mechanic @ $15/hr plus one driver @ $10/hr for 13 days = $5,100

Labor for Stationary Test: one engineer for 3 months @ $20/hr = $10,400; 1/2 day of testing per week for 3 months = 6 1/2 days; one technician @ $12/hr plus one mechanic @ $15/hr for 6 1/2 days = $1,400.

Test Site @ $100/day for 13 days = $1,300

Motorcycle Lease: A $90 wholesale exhaust system is exchanged for use of each motorcycle in the testing. 10 motorcycles @ $90/motorcycle = $900.

Transportation Costs: $10/motorcycle for 10 motorcycles for 13 days = $1,300

Test Equipment: $2624 with a 4 to 5 year life = $600/year divided equally between R&D testing costs and compliance testing costs.

Table 7-20 C

YEARLY COMPLIANCE TESTING COSTS FOR A LARGE EXHAUST SYSTEM MANUFACTURER USING THE FEDERAL PASS-BY TEST (8 EXHAUST SYSTEMS TESTED PER DAY)

	30 Exhaust Systems	5 Exhaust Systems
Labor	$1,568 (4 days)	$392 (1 day)
Site	400	100
Motorcycle Costs	--	--
Transportation	300	50
Administrative Costs (15%)	340	81
Equipment	300	300
	$2,908	$923

YEARLY COMPLIANCE TESTING COSTS FOR A SMALL EXHAUST SYSTEM MANUFACTURER USING THE FEDERAL PASS-BY TEST (8 EXHAUST SYSTEMS TESTED PER DAY)

	12 Exhaust Systems	2 Exhaust Systems
Labor	$ 784 (2 days)	$ 392 (1 day)
Site	200	100
Motorcycle Costs	--	--
Transportation	120	20
Administrative Costs (15%)	165	76
Equipment	300	300
	$1,569	$888

Table 7-20 D

YEARLY COMPLIANCE TESTING COSTS FOR A LARGE MANUFACTURER USING THE F50 STATIONARY TEST (16 EXHAUST SYSTEMS TESTED PER DAY)

	30 Systems
Labor	$ 432 (2 days)
Site	--
Motorcycle Cost	--
Transportation & Administrative Costs	300
Equipment	300
	$1,032

YEARLY COMPLIANCE TESTING COSTS FOR A SMALL MANUFACTURER USING THE F50 STATIONARY TEST (16 EXHAUST SYSTEMS TESTED PER DAY)

	12 Systems
Labor	$ 216 (1 day)
Site	--
Motorcycle Costs	--
Transportation & Administrative Costs	120
Equipment	300
	$ 636

Table 7-20 E

AVERAGE YEARLY COSTS OF R&D[1] AND PV TESTING AFTERMARKET EXHAUST SYSTEM MANUFACTURERS FOR THE FEDERAL PASSBY TEST VS. THE F50 STATIONARY TEST

Level of Standard	Large Manufacturer[2] (Passby Test/F50 Test)	Small Manufacturer[3] (Passby Test/F50 Test)
83/86 dB for Street/Off-road Amortized Over the 3 Year Period		
R&D	$3200/$2200	$1300/$ 900
PV Testing	1600/ 700	1100/ 600
Total	4800/ 2900	2400/ 1500
80/82 dB for Street/Off-road Amortized Over the Initial 3 Year Period		
R&D	$6300/$4300	$ 2500/$1700
PV Testing	1600/ 700	1100/ 600
Total	7900/ 5000	3600/ 2300
80/82 dB for Street/Off-road After Initial 3 Year Period		
R&D	--	--
PV Testing	$ 900/$600	$ 900/$ 600
Total	900/ 600	900/ 600

---

1. R & D includes cost of redesign and prototype testing
2. Large manufacturer revenues are assumed to be 1 million
3. Small Manufacturer revenues are assumed to be 200,000

Table 7-20 F

Average Price Increase of Aftermarket Exhaust System Due to R&D and PV Testing by the Federal Passby Test vs. the F50 Stationary Test

(Passby Test/F50 Test)

Level of Standard	Large Manufacturer	Small Manufacturer
83/86 dB for Street/Off-road Amortized Over the 3 Year Period		
R&D	1.0%/0.7%	2.0%/1.4%
PV Testing	0.5%/0.2%	1.7%/0.9%
Total	1.5%/0.9%	3.7%/2.3%
80/82 dB for Street/Off-road Amortized Over the Initial 3 Year Period		
R&D	2.0%/1.4%	3.9%/2.7%
PV Testing	0.5%/0.2%	1.7%/0.9%
Total	2.5%/1.6%	5.6%/3.6%
80/82 dB for Street/Off-road After Initial 3 Year Period		
R&D	0	0
PV Testing	0.09%/0.06%	0.05%/0.03%
Total	0.09%/0.06%	0.05%/0.03%

Table 7-20

ESTIMATED COST OF COMPLIANCE TESTING -

MANUFACTURER SUPPLIED DATA
(1975 DOLLARS)

Manufacturer A

Additional test equipment and facilities cost:

1. Additional test site for SAE J331a ---- $100,000.
2. Six sets of equipment for performing ISO stationary vehicle measurements ---- $180,000.

Test operations and administration costs:

1. Sampling inspections by SAE J331a of three units/model/month at 3 units/day ---- $16,000 per year.
2. ISO stationary inspection of motorcycles for U.S.

100% inspection	$200,000 per year
1% inspection	$ 2,000 per year

Manufacturer B

Additional Test Equipment and Facilities:

$250,000 - $400,000 depending on type of testing.

Test Operations and Administration Costs:

$100,000 - $300,000 per year depending on required levels of production verification.

Manufacturer C

Additional Test Equipment and Facilities Cost:	$300,000
Test Operations and Administration Cost:	$300,000 per year.

Table 7-21

ESTIMATE OF ANNUAL TESTING AND

CERTIFICATION COSTS--MAJOR MANUFACTURER
(1975 DOLLARS)

COST COMPONENT					COST
Production Verification	25 models	1 test each			
(see enforcement section)	3 persons	1 hr/test	75 hr		
Selective Enforcement Audit	3 models	15 vehicles/model			
(see enforcement section)	3 persons	1 hr/test	135 hr		
Label Verification	25 models	30 test each	125 hr		
(see enforcement section)	2 persons	5 min/test			
Reporting & Administration			250 hr		
		Total	585 hr	At $20/hr	$11,700
Materials and Miscellaneous					5,000
		Total			$16,700

7.1.5 Total Weighted Unit Cost Increases

Total unit cost increases resulting from compliance with noise standards arise from four major cost elements:

(1) Manufacturing unit cost increases.

(2) Amortized R&D costs on a unit basis.

(3) Amortized tooling costs on a unit basis.

(4) Compliance testing and certification costs on a unit basis.

The total unit cost increases at various regulatory levels for the several motorcycle product categories are summarized in Table 7-4. A breakdown of total unit costs by major cost element is provided in Tables 7-22 and 7-23. As has been indicated, in general, the largest contributor to the unit cost increase is the manufacturing cost, which typically ranges from between 60 to 70 percent of the total, followed by amortized R&D costs, unit tooling costs, and the testing and certification costs.

Probable unit cost increases for compliance with the noise emission standards were determined for all motorcycles that were tested. These costs were then weighted by the percentage of the total market share for each manufacturer in each engine displacement class and totaled to obtain unit cost increases for various regulatory levels of each engine displacement class. These calculations were made for both street-legal and off-road motorcycles and for nominal (expected) and worst cases. Refer to Table 7-24 for projected weighted total unit cost increases for the various regulatory levels.

7.2 Purchase Price Impacts

The impact of cost increases on motorcycle purchase prices is a complex situation and one which will be determined in the final analysis by free market interaction between supply and demand. However, some of the cost scenarios which are likely to occur as a result of the interaction of these economic forces are presented in this section.

Table 7-25 provides an approximation of the existing price mark-up structure between manufacturer and distributor (if any) and dealer. Distributors for major manufacturers are generally wholly owned subsidiaries.

One manufacturer indicated that typical price mark-ups range between 20 to 40 percent at the retail level. Independent references tend to support this estimate. Generally, EPA assumes the worst-case price increase due to an incremental change in cost is assumed to be 50 percent. However, the impact on price could range from a unit price increase being slightly less than a unit cost increase to a price increase equal to 1.5 times the cost increase. Representative cases in which four different levels of mark-up could occur are described following Table 7-25.

Cases I and II would be considered very optimistic, primarily because they are counter to normal mark-up policies, even for "incremental" cost

Table 7-22

TOTAL UNIT COST INCREASE ELEMENTS: NOMINAL (EXPECTED) CASE (1978 DOLLARS)

	UNIT COST INCREASE (DOLLARS)				
	REGULATORY NOISE LEVELS[1] (SAE J331a)				
	86 dB	83 dB	80 dB	78 dB	75 dB
STREET LEGAL, 750 cc Over					
Manufacturing Cost	*	12	44	113	220
R&D[2]	*	2	13	33	53
Tooling[3] (Mfg. Equipment)	*	6	12	27	46
Compliance Testing & Certification Cost	*	2	2	2	2
Total	*	22	71	175	321
STREET LEGAL, 350-749 cc					
Manufacturing Cost	*	9	29	90	186
R&D	*	2	13	33	53
Tooling (Mfg. Equipment)	*	6	12	27	46
Compliance Testing & Certification Cost	*	2	2	2	2
Total	*	19	56	152	287
STREET LEGAL, 170-349 cc					
Manufacturing Cost	*	5	23	67	136
R&D	*	2	13	33	53
Tooling (Mfg. Equipment)	*	6	12	27	46
Compliance Testing & Certification Cost	*	2	2	2	2
Total	*	15	50	129	237
STREET LEGAL, 100-169 cc					
Manufacturing Cost	*	3	13	52	100
R&D	*	1	2	14	33
Tooling (Mfg. Equipment)	*	0	1	6	13
Compliance Testing & Certification Cost	*	2	2	2	2
Total	*	6	18	74	148

---

1. Not-to-exceed regulatory levels.
2. Amortized R&D costs on a unit basis.
3. Amortized tooling costs on a unit basis.

* Information not available

Table 7-22 (Cont'd)

TOTAL UNIT COST INCREASE ELEMENTS: NOMINAL (EXPECTED) CASE (1978 DOLLARS)

	UNIT COST INCREASE (DOLLARS)				
	REGULATORY NOISE LEVELS[1] (SAE J331a)				
	86 dB	83 dB	80 dB	78 dB	75 dB
STREET LEGAL, 99 cc BELOW					
Manufacturing Cost	0	0	0	9	21
R&D[2]	0	0	0	2	14
Tooling (Mfg.[3] Equipment)	0	0	0	6	13
Compliance Testing & Certification Cost	*	2	2	2	2
Total	0	2	2	19	50
OFF-ROAD, 350-749 cc					
Manufacturing Cost	5	13	100	123	*
R&D	1	2	13	33	*
Tooling (Mfg. Equipment)	0	6	12	27	*
Compliance Testing & Certification Cost	0	2	2	2	*
Total	6	23	127	185	*
OFF-ROAD, 170-349 cc					
Manufacturing Cost	5	10	49	93	*
R&D	1	2	13	33	*
Tooling (Mfg. Equipment)	0	6	12	27	*
Compliance Testing & Certification Cost	0	2	2	2	*
Total	6	20	76	155	*
OFF-ROAD, 100-169 cc					
Manufacturing Cost	0	3	10	73	*
R&D	0	1	2	14	*
Tooling (Mfg. Equipment)	0	0	6	6	*
Compliance Testing & Certification Cost	-	2	2	2	*
Total	0	6	20	95	*

---

1. Not-to-exceed regulatory levels.
2. Amortized R&D costs on a unit basis.
3. Amortized tooling costs on a unit basis

* Information not available

Table 7-22 (Cont'd)

TOTAL UNIT COST INCREASE ELEMENTS
NOMINAL (EXPECTED) CASE
(1978 DOLLARS)

	UNIT COST INCREASE (DOLLARS) REGULATORY NOISE LEVELS[1] (SAE J331a)			
	86 dB	83 dB	80 dB	78 dB
OFF-ROAD, 99 cc & BELOW				
Manufacturing Cost	0	0	0	9
R&D[2]	0	0	0	2
Tooling (Mfg.[3] Equipment)	0	0	0	6
Compliance Testing & Certification Cost	0	2	2	2
Total	0	2	2	19

---

1. Not to exceed regulatory levels.
2. Amortized R&D costs on a unit basis.
3. Amortized tooling costs on a unit basis.

Table 7-23

TOTAL UNIT COST INCREASE ELEMENTS
WORST CASE
(1978 DOLLARS)

	UNIT COST INCREASE (DOLLARS)				
	REGULATORY NOISE LEVELS[1] (SAE J331a)				
	86 dB	83 dB	80 dB	78 dB	75 dB
STREET LEGAL, 750 cc OVER					
Manufacturing Cost	0	12	78	155	226
R&D[2]	0	2	26	46	55
Tooling (Mfg.[3] Equipment)	0	6	24	44	49
Compliance Testing & Certification Cost	0	2	2	2	2
Total	0	22	130	247	332
STREET LEGAL, 350-749 cc					
Manufacturing Cost	0	9	60	118	191
R&D	0	2	26	46	55
Tooling (Mfg. Equipment)	0	6	24	44	49
Compliance Testing & Certification Cost	0	2	2	2	2
Total	0	19	112	210	297
STREET LEGAL, 170-349 cc					
Manufacturing Cost	0	5	44	88	140
R&D	0	2	26	46	55
Tooling (Mfg. Equipment)	0	6	24	44	49
Compliance Testing & Certification Cost	0	2	2	2	2
Total	0	15	96	180	246
STREET LEGAL, 100-169 cc					
Manufacturing Cost	0	3	35	74	105
R&D	0	1	2	27	47
Tooling (Mfg. Equipment)	0	0	24	44	49
Compliance Testing & Certification Cost	0	2	2	2	2
Total	0	6	63	147	203

---

1. Not to exceed regulatory levels.
2. Amortized R&D costs on a unit basis.
3. Amortized tooling costs on a unit basis.

Table 7-23 (Cont'd)

TOTAL UNIT COST INCREASE ELEMENT
WORST CASE
(1978 Dollars)

	UNIT COST INCREASE (DOLLARS)			
	REGULATORY NOISE LEVELS[1] (SAE J331a)			
	86 dB	83 dB	80 dB	78 dB
OFF-ROAD, 350-749 cc				
Manufacturing Cost	5	13	99	122
R&D[2]	1	2	26	46
Tooling (Mfg.[3] Equipment)	0	6	24	44
Compliance Testing & Certification Cost	0	2	2	2
Total	6	23	151	214
OFF-ROAD, 170-349 cc				
Manufacturing Cost	5	10	71	93
R&D	1	2	26	46
Tooling (Mfg. Equipment)	0	6	24	44
Compliance Testing & Certification Cost	0	2	2	2
Total	6	20	123	185
OFF-ROAD, 100-169 cc				
Manufacturing Cost	0	3	57	74
R&D	0	1	2	27
Tooling (Mfg. Equipment)	0	0	21	44
Compliance Testing & Certification Cost	0	2	2	2
Total	0	6	82	147

---

1. Not-to-exceed regulatory levels.
2. Amortized R&D costs on a unit basis.
3. Amortized tooling costs a unit basis.

Table 7-24

PROJECTED WEIGHTED TOTAL UNIT COST INCREASES VERSUS REGULATORY LEVELS
NOMINAL AND WORST CASE
(1978 DOLLARS)

	TOTAL WEIGHTED UNIT COST INCREASE REGULATORY NOISE LEVELS (SAE J331a)				
PRODUCT CLASSIFICATION	86 dB	83 dB	80 dB	78 dB	75 dB
NOMINAL (EXPECTED) CASE					
99 cc and Below	0	1	1	16	64
100-169 cc	0	1	8	64	138
170-349 cc	0	3	34	102	210
350-749 cc	0	5	30	99	241
750 cc and Above	0	9	47	144	289
Average Street-Legal	0	5	30	100	221
99 cc and Below	0	2	2	18	*
100-169 cc	0	1	5	35	*
170-349 cc	3	20	76	156	*
350-749 cc	6	23	127	185	*
Average Off-Road	1	7	26	60	*
FLEET AVERAGE	0	6	29	89	*
WORST CASE					
99 cc and Below	0	1	1	16	64
100-169 cc	0	1	33	117	173
170-349 cc	0	3	63	140	210
350-749 cc	0	5	67	149	241
750 cc and Above	0	9	92	201	289
Average Street-Legal	0	5	63	147	226
99 cc and Below	0	2	2	18	*
100-169 cc	0	1	23	54	*
170-349 cc	3	20	122	184	*
350-749 cc	6	23	151	214	*
Average Off-Road	1	7	41	72	*
FLEET AVERAGE	0	6	57	127	*

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* Information not available

Table 7-25

NEW MOTORCYCLE PRICE MARK-UPS

LEVEL	MFG. EST.	PRICE REF. SOURCES A.	B.	C.	PERCENTAGE MARK-UP CONSENSUS Mark-Up	Cum Mark-Up
New Motorcycle Manufacturers	6 to 12%	-	-	-	-	-
Distributors[1]	20%	0-25%	12-15%		0-25%	0-25%
Dealers	40%	33%	20-25%	33%	20-33%	20-66%

Note: 1. Significant price discounting can occur at this level.

Sources:
- A. International Research and Technology Corporation. "The Impact of Noise Abatement Standards on the Motorcycle Industry."
- B. Manufacturer supplied confidential data.
- C. Motorcycle Industry Council, "Manufacturer's Shipment Reporting System."

REPRESENTATIVE CASES DEPICTING FOUR DIFFERENT MARK-UP LEVELS

Case	Price Mark-Up Factor	Conditions
I	0.9	This would occur if the manufacturer absorbed part of the incremental cost increase, and distributors and dealers reduced their mark-up factors to allow for straight pass-through of cost increase.
II	1.0	This would occur if manufacturers, distributors and dealers passed increased cost straight through to consumers.
III	1.2	This would occur if manufacturer and distributors passed costs straight through to dealers and dealers either used their standard mark-up or discounted their prices.
IV	1.5	This would occur if unit cost increase is marked-up by standard rates at each level.

increases. Case III is a more likely possibility because it takes into account both level of demand and profitability. Case IV would be considered worst case, because this is the mark-up factor that would impact demand severely. If these mark-up factors reduced demand significantly, discounting and manufacturing rebate actions would likely take place, thereby reducing effective mark-up factors to those shown in Case III. The 1.2 factor is therefore a relatively realistic estimate and is used in the "nominal" case analysis. The 1.5 factor is used in the "worst-case" analysis.

Total weighted unit cost increases determined in the cost analysis are used as the basis of estimating price increases (refer to Table 7-24). In the nominal case, total weighted unit cost increases are factored by the 1.2 price mark-up factor derived in the previous section to determine price increases and in the worst case, total weighted unit costs were factored by a 1.5 price mark-up factor. The results for the two cases and for each product category are summarized in Table 7-26, and shown in Figures 7-5 through 7-8. These price impacts are for regulatory levels as defined by the SAE J331a test procedure.

The projected average unit price increases for street-legal, off-road, and all motorcycles for nominal and worst cases are shown in Figures 7-9 and 7-10.

Average 1978 prices for each of the product categories are shown in Table 7-27. These prices were used as the baseline reference to compute the relative price increases which are also summarized in Table 7-27.

7.3 Replacement Exhaust System Price Impacts

Using manufacturer-supplied data and an independent estimate, the purchase price increases expected for 4 into 1 and 2 into 1 exhaust systems were calculated and are shown in Tables 7-28, 7-29, and 7-30.

Projected relative price increases for two typical exhaust systems are summarized as follows:

Regulatory Level	4 into 1 Exhaust System	2 into 1 Exhaust System
80 dB	+21%	+26%
78 dB	+40%	+50%

7.4 Operational Cost Increases

As discussed in Section 6.3 the principal operational cost increases associated with lower levels of noise are the impact on fuel economy. Based on the fuel penalties in Section 6.3.2, the "nominal" and "worst" case esti-

Table 7-26

PROJECTED MOTORCYCLE PRICE INCREASES FOR VARIOUS J331a REGULATORY LEVELS (1978 DOLLARS)1.

PRODUCT CATEGORY	UNIT PRICE INCREASE REGULATORY LEVEL (SAE J331a) 86 dB	83 dB	80 dB	78 dB	75 dB
NOMINAL CASE					
Street-Legal					
99 cc and Below	0	1	1	19	77
100-169 cc	0	1	10	77	166
170 - 349 cc	0	4	41	122	252
350 - 749 cc	0	6	36	119	289
750 cc and Above	0	11	56	173	347
Average street-legal	0	6	36	120	265
Off-Road					
99 cc and Below	0	2	2	22	*
100 - 169 cc	0	1	6	42	*
170 - 349 cc	4	24	91	187	*
350 - 749 cc	7	28	152	222	*
Average off-road	1	8	31	73	*
Fleet Average	0	6	35	108	*
WORST CASE					
Street-Legal					
99 cc and Below	0	1	1	24	96
100 - 169 cc	0	1	50	176	260
170 - 349 cc	0	4	94	210	315
350 - 749 cc	0	7	100	224	362
750 cc and Above	0	13	138	301	434
Average street-legal	0	7	94	221	340
Off-Road					
99 cc and Below	0	2	2	27	*
100 - 169 cc	0	1	34	81	*
170 - 349 cc	4	30	183	276	*
350 - 749 cc	9	34	226	321	*
Average off-road	1	9	60	108	*
Fleet Average	0	7	85	191	*

---

1. 1978 dollars -- Based on projected weighted total unit cost increases
* Information not available

FIGURE 7-5 PROJECTED RETAIL PRICE INCREASES VS. REGULATORY NOISE LEVELS FOR STREET LEGAL MOTORCYCLES

—nominal case—

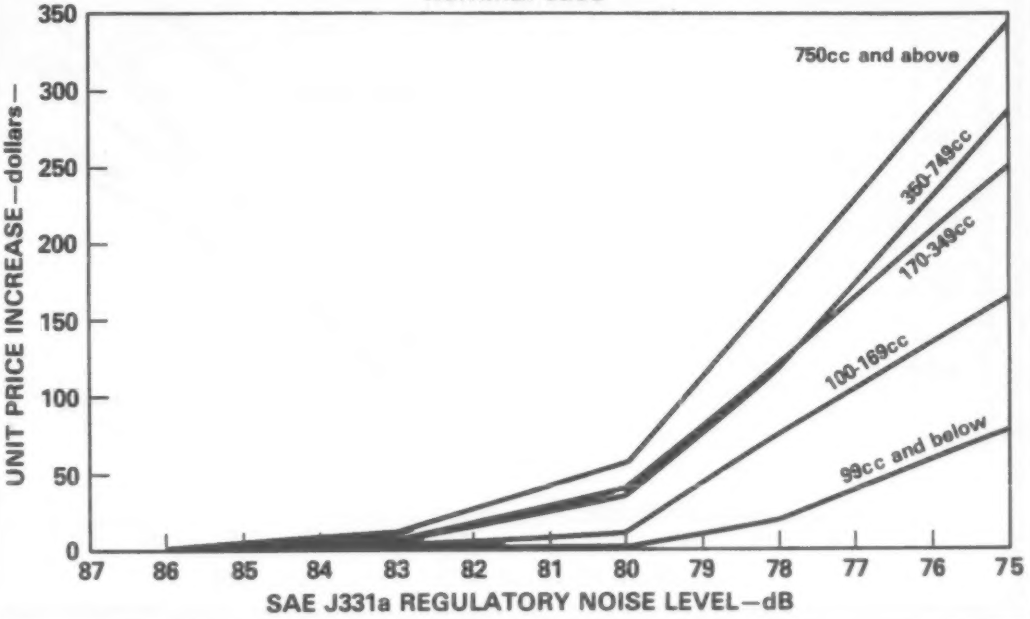

FIGURE 7-6 PROJECTED RETAIL PRICE INCREASES VS. REGULATORY NOISE LEVELS FOR OFF-ROAD MOTORCYCLES

—nominal case—

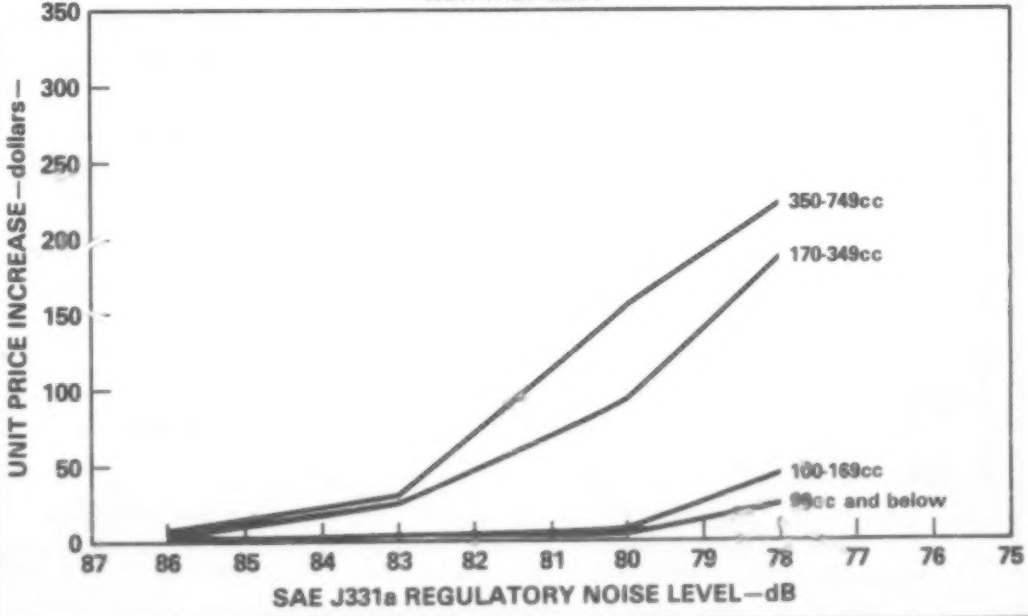

FIGURE 7-7 PROJECTED RETAIL PRICE INCREASES VS. REGULATORY NOISE LEVELS FOR STREET LEGAL MOTORCYCLES

—worst case—

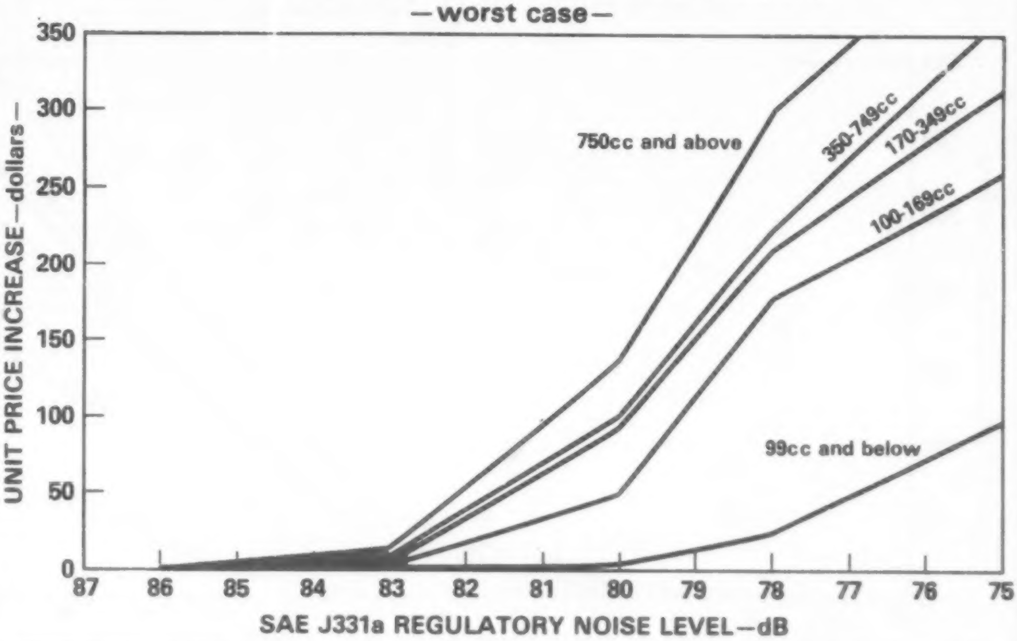

FIGURE 7-8 PROJECTED RETAIL PRICE INCREASES VS. REGULATORY NOISE LEVELS FOR OFF-ROAD MOTORCYCLES

—worst case—

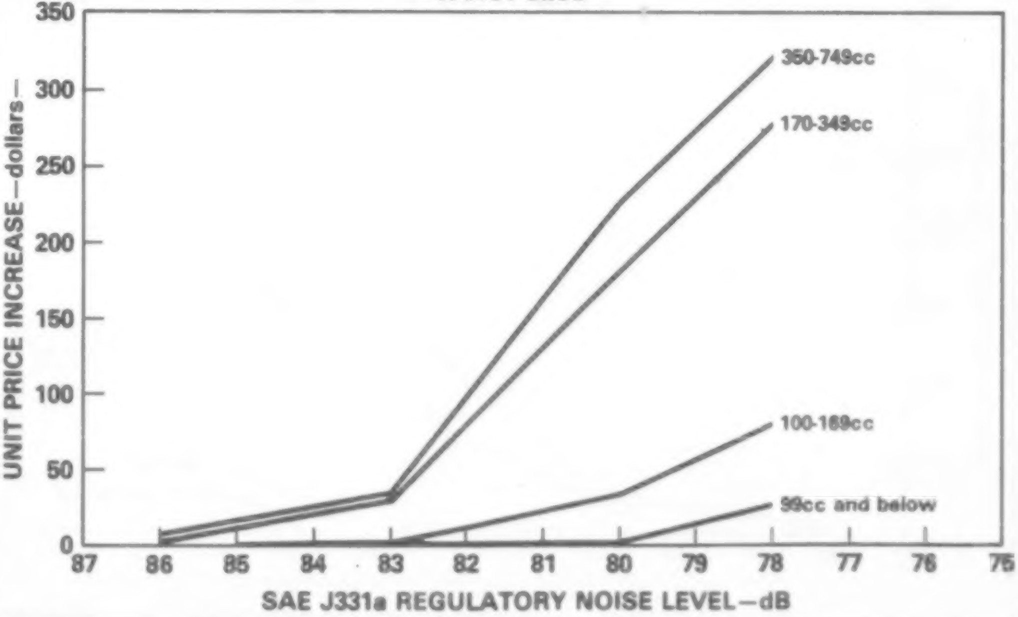

FIGURE 7-9 WT. AVG. PRICE/dB

—nominal case—

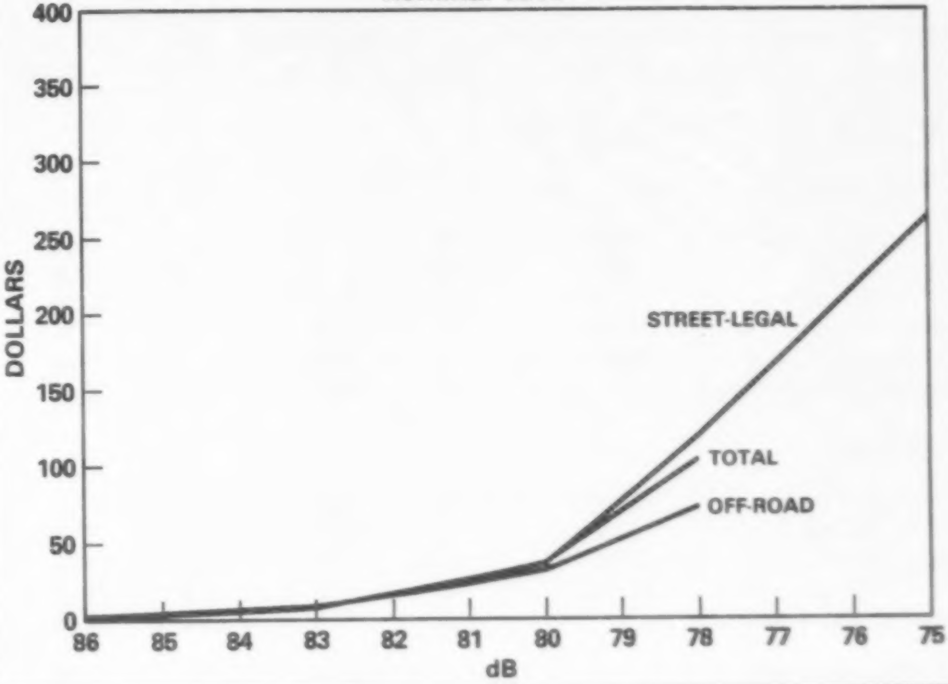

FIGURE 7-10 WT. AVG. PRICE/dB

—worst case—

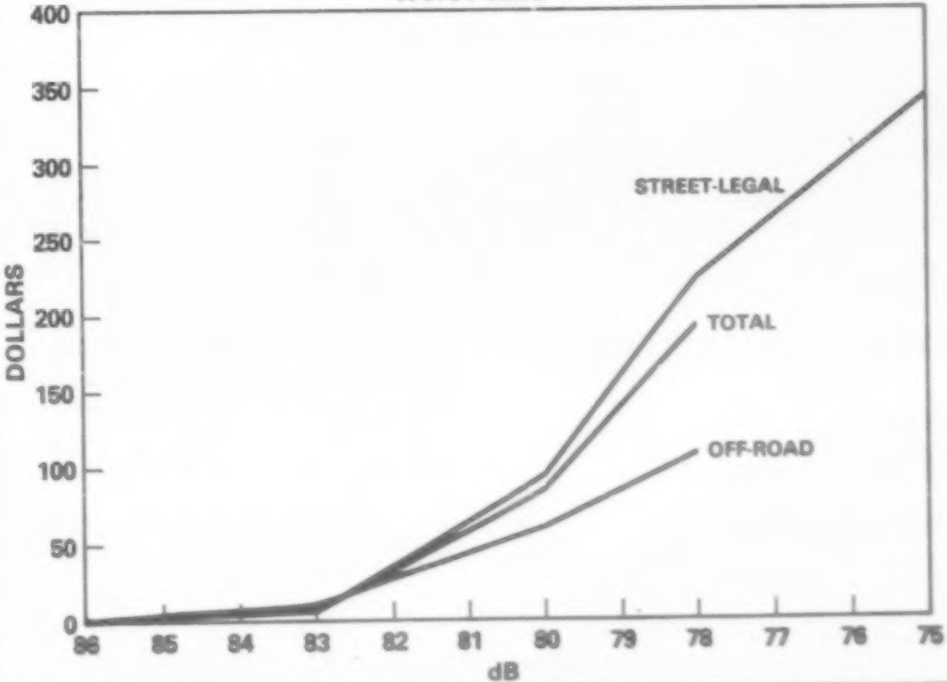

Table 7-27

PROJECTED MOTORCYCLE PRICE INCREASES ON A RELATIVE BASIS (1978 DOLLARS)

PRODUCT CATEGORY	Baseline 1978 Price (Dollars)	RELATIVE PRICE INCREASE (%) REGULATORY LEVEL (SAE J331a)				
		86 dB	83 dB	80 dB	78 dB	75 dB
NOMINAL CASE						
Street-Legal						
99 cc and Below	$581	0	0.2	0.2	3.3	13.2
100 - 169 cc	$806	0	0.1	1.2	9.6	20.6
170 - 349 cc	$1188	0	0.3	3.5	10.4	21.6
350 - 749 cc	$1596	0	0.4	2.2	7.4	18.1
750 cc and Above	$2943	0	0.4	1.9	5.6	11.8
Average Street-Legal		0	0.3	2.0	7.6	17.1
Off-Road						
99 cc and Below	$589	0	0.3	0.3	3.7	*
100 - 169 cc	$806	0	0.1	0.7	5.2	*
170 - 349 cc	$1321	0.2	1.8	6.9	14.2	*
350 - 749 cc	$1540	0.4	1.8	9.9	14.4	*
Average Off-Road		0.1	1.8	2.4	6.8	*
All Motorcycles		0	0.4	2.1	7.4	*
WORST CASE						
Street-Legal						
99 cc and Below	$581	0	0.2	0.2	4.1	16.5
100 - 169 cc	$806	0	0.1	6.2	21.8	32.2
170 - 349 cc	$1168	0	0.3	8.0	18.0	27.0
350 - 749 cc	$1596	0	0.4	6.3	14.0	22.7
750 cc and Above	$2948	0	0.4	4.7	10.2	14.7
Average Street Legal		0	0.3	5.7	14.2	22.4
Off-Road						
99 cc and Below	$589	0	0.3	0.3	4.6	*
100 - 169 cc	$806	0	0.1	4.2	10.0	*
170 - 349 cc	$1321	0.2	2.3	13.8	20.9	*
350 - 749 cc	$1540	0.4	2.2	14.7	20.8	*
Average Off-Road		0.1	0.8	4.8	10.1	*
All Motorcycles		0	0.4	5.5	13.1	*

---

* Information not available

Table 7-28

EXHAUST SYSTEMS
TYPICAL PRICE MARK-UPS
(1978 DOLLARS)

Cost/Price	4 into 1 Exhaust System Dollars (1978)	2 into 1 Exhaust System Dollars (1978)
Muffler Cost[1]	$24	$21
Header Cost[1]	$48	$24
Total Cost	$72	$45
Profit Margin[2]	$ 9	$ 5
Net to Distributor[2]	81	50
Net Price to Dealer[2]	113	70
Suggested Retail Price[2]	170	105

Sources:
1. Independent cost estimate
2. Manufacturer supplied data

Table 7-29

INCREASE IN MUFFLER COSTS FOR VARIOUS REGULATORY LEVELS (1978 DOLLARS)

Muffler	Baseline Cost	Regulatory Level (SAE J331a) 83 dB	80 dB	78 dB
4 into 1*	$22.5	$30	$39	$52
Percentage Increase	--	+33%	+72%	+133%
2 into 1**	$21	$26	$32	$43
Percentage Increase	--	+24%	+52%	+106%

* Motorcycle 750 cc and above assumed
** Motorcycle 250-749 cc assumed

Source: Independent Estimate

Table 7-30

INCREASE IN EXHAUST SYSTEM PRICES FOR VARIOUS REGULATORY LEVELS (1978 DOLLARS)

Exhaust System	Baseline Cost	Regulatory Level (SAE J331a) 83 dB	80 dB	78 dB
4 into 1	$170	$185	$206	$238
Percentage Increase	--	+9%	+21%	+40%
2 into 1	$105	$117	$132	$158
Percentage Increase		+11%	+26%	+50%

mates for fractional reduction in fuel economy are listed in Table 7-31 (all size categories combined):

Table 7-31

		Regulatory Level [(A-weighted], SAE J331a)			
		Present			
		83 dB	80 dB	78 dB	75 dB
Street:	Nominal Case	0	2	7.5	14
	Worst Case	0	4	12	15
Off-road:	Nominal Case	0.5	4	7	--
	Worst Case	1	5	8	--

Several motorcycle magazines routinely measure fuel economy in the course of testing motorcycles. Testing sequences are not generally specified and tend to vary from test to test and magazine to magazine. However, a review of published data for Cycle and Cycle Guide magazine in 1975 indicate that estimates of 45 m.p.g. for street motorcycles over 170 cc and 70 m.p.g. for street motorcycles 170 cc and under are reasonably consistent with reported results. These estimates generally agree with manufacturer-supplied information. The data in Section 5 indicate that motorcycles under 170 cc travel about 2/3 the annual distance of motorcycles over 170 cc. Further the data in Section 2 indicate that motorcycles under 170 cc make up approximately six percent of the street motorcycle population. These figures can be combined for a composite fuel economy of current street motorcycle of about 47 m.p.g. Two-stroke engines generally display somewhat lower fuel economy than 4-stroke models, but large consistent differences were not noted. From these same reports, 35 m.p.g. for pure off-road motorcycle over 170 cc and 7.0 m.p.g. for off-road motorcycles under 170 cc is assumed. Mileage data indicate no significant difference in annual mileage between large and small motorcycles, so these can be combined for a composite 60 m.p.g. figure. Table 7-32 shows the annual increases in fuel costs for both street and off-road motorcycles.

Table 7-32

		Regulatory Level [(A-weighted], SAE J331a) (Dollar/Year)				
		86 dB	83 dB	80 dB	78 dB	75 dB
Street:	Nominal Case		0	0.48	1.80	3.35
	Worst Case		0	0.96	2.87	3.59
Off-road:	Nominal Case	0	0.03	0.26	0.46	--
	Worst Case	0	0.07	0.33	0.53	--

7.5 Maintenance Costs

Estimates were made in Section 6.3 on the additional number of labor hours per year required to maintain motorcycles as a result of noise reduction. There has been no indication that at designing to meet lower noise level standards result in exhaust systems or other parts are any less durable than current systems; therefore, no increase in maintenance is expected. The nominal and worst case increased labor estimates are listed in Table 7-33 below (all size categories combined; hours/years):

Table 7-33

		Regulatory Level [(A-weighted), SAE J331a]				
		86 dB	83 dB	80 dB	78 dB	75 dB
Street:	Nominal Case		0	1/4	1/2	3/4
	Worst Case		0	3/8	3/4	3/4
Off-road:	Nominal Case	0	1/16	1/4	3/8	--
	Worst Case	0	1/8	3/8	1/2	--

Although many motorcyclists do their own maintenance, maintenance at a moderately priced repair facility with a labor rate of $20/hour is assumed for costing purposes. The resulting increased annual maintenance costs are listed in Table 7-34 below (1975 dollars/year):

Table 7-34

		Regulatory Level [(A-weighted), SAE J331a]				
		86 dB	83 dB	80 dB	78 dB	75 dB
Street:	Nominal Case		0	5	10	15
	Worst Case	0		7.5	15	15
Off-road:	Nominal Case	0	1	5	5	--
	Worst Case	0	2	7.5	10	--

7.6 Costs of EPA Air Emission Requirements

The assessed costs and impacts of the noise regulation of motorcycles will be in addition to those costs and impacts attributable to EPA's motorcycle air emission regulations (40 FR 1122, January 5, 1977). EPA studies using information supplied by various manufacturers indicate that the cost of compliance with the air emission standards for 1978 would result in an average increase in retail cost of $47 per motorcycle. Also, the manufacturers estimated that fuel economy improvements associated with the 1978 air emission standards would range as high as 65 percent with an average increase of 20 percent. Consequently, air emission control costs would be partially offset by an average discounted lifetime fuel savings of $33 and an undetermined savings in maintenance and improved reliability of the product. The average incremental cost increase for the 1980 air emission standards was estimated to be $9, which included a small additional improvement in fuel economy. No significant decrease in sales or shift in market shares (between manufacturers) was expected to result from the implementation of the air emission regulation.

SECTION 8

ECONOMIC IMPACT ANALYSIS

SECTION 8

ECONOMIC IMPACT STATEMENT

8.1. New Motorcycle Sales

New motorcycle sales are analyzed first from a historical perspective, using actual sales figures from 1967-1978. and second on the basis of a sales forecasting model. Although the monthly forecasts of demand begin in January of 1979, the coefficients of the demand equations used for forecasting were estimated with January 1973 - December 1975 data.*

8 1.1 Historical New Motorcycle Sales and Trends

The trends in the consumer demand for new motorcycles, as shown in Table 8-1, have closely followed the behavior of the overall economy from 1967-1978. Note that the new registration figures from R. L. Polk and Company shown in Table 8-1 and Figure 8-2 are not equivalent to total new motorcycle sales (Figure 8-1). since off-road and competition models are not required to be registered in most states. The total motorcycle sales data for the 1972-1978 period was derived from the "Motorcycle Industry Council's Manufacturing Shipment Reporting System," which is an account of motorcycle shipment to dealers for the six (five, after 1975) largest manufacturers.

Definitions used in the Manufacturers Shipment Reporting System are in Table 8-2. The reporting system was specially designed to provide sales data for the product categories shown in Table 8-3.

The Motorcycle Industry Council provided EPA with complete monthly sales data from January, 1972, through December, 1978, for total motorcycle unit sales. which included retail, wholesale, and regional sales data.

8.1.2 Sales by Product Category

The breakdown of 1978 sales by product category shown in Table 8-4 and Figure 8-3 indicates that street motorcycles accounted for one-half of sales total. Over two-fifths of the motorcycles (41.7 percent) are street motorcycles 350 cc and above. The majority of the motorcycles in this category have 4-stroke engines. Almost all of the off-road motorcycles from 125 to 349 cc have 2-stroke engines.

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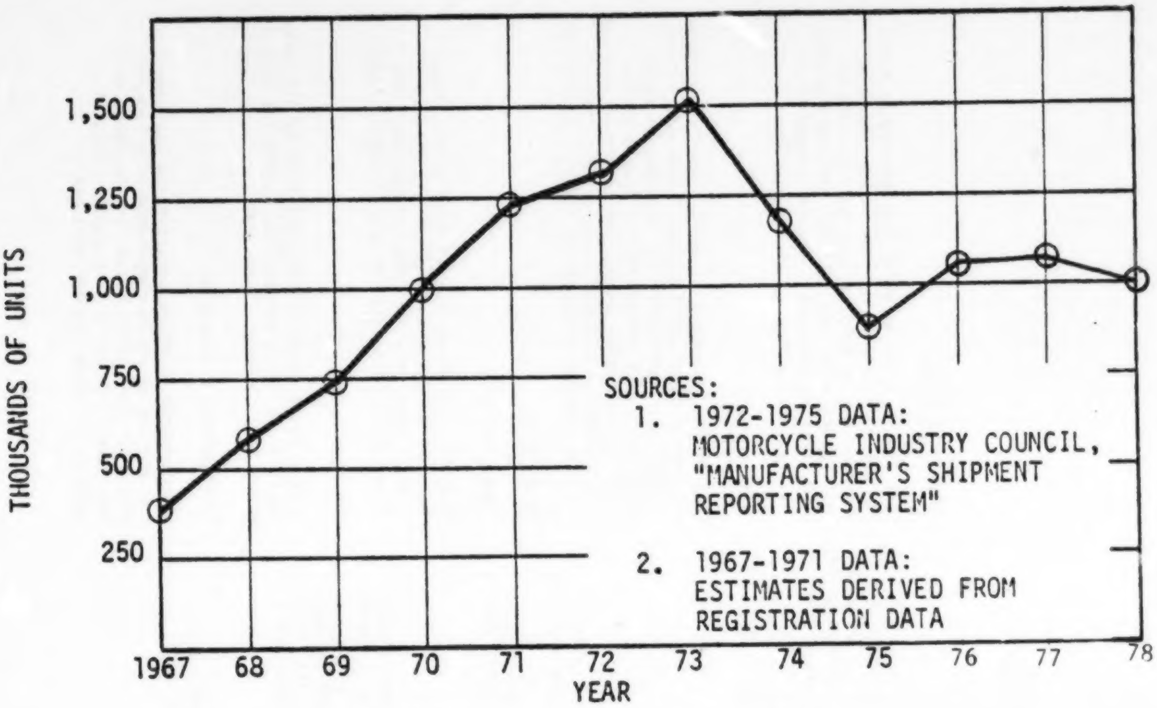
* Some of the engine-size categories (i.e., under 100 cc's, 100-169 cc's and 170-349 cc's), for each of which there corresponds a set of demand coefficients, do not lend themselves to forecasting because these categories were created specifically for this research only for 1973-1975 by the Motorcycle Industry Council. Although useful for analysis, these categories cannot be recreated for 1976, 1977, or 1978. however, the demand for these motorcycle categories combined can be derived as a residual of the forecasted demand for all motorcycles, after subtracting the forecasted demand for all other size classes.

Table 8-1

NEW MOTORCYCLE UNIT SALES DATA (1967-1978)(1)

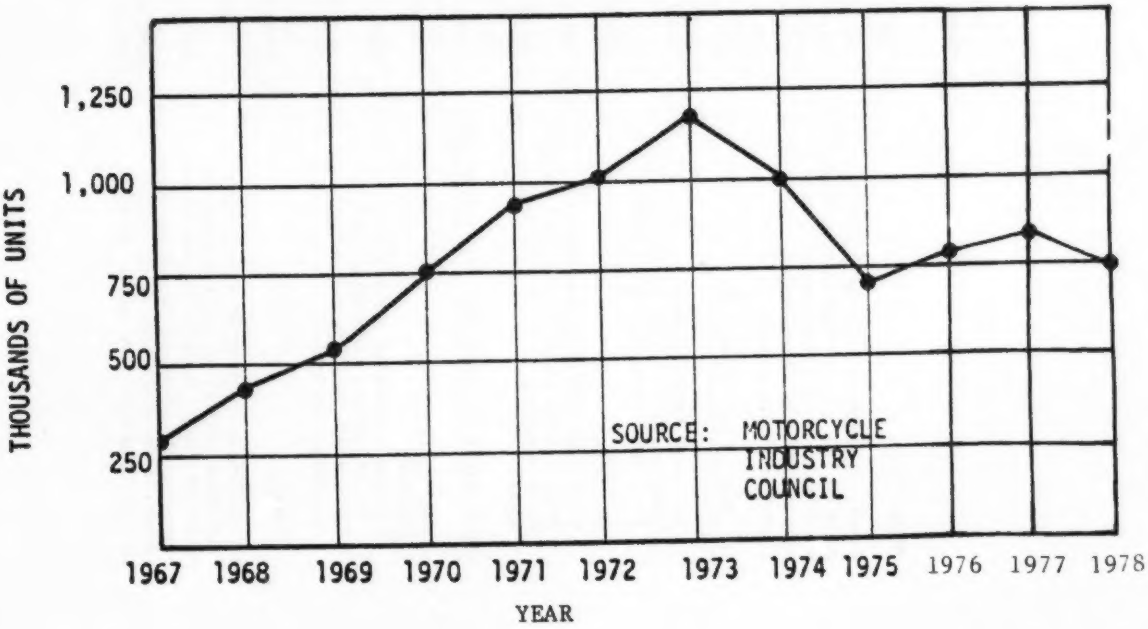
Year	New Motorcycle Registrations (1)	New Motorcycles Sold (Est.)	Changes from Previous Year
1978	764,097	998,186	- 7%
1977	848,588	1,077,280(2)	+ 3%
1976	783,100	1,049,378(2)	+19%
1975	746,778	880,075(2)	-25%
1974	1,024,084	1,181,395(2)	-22%
1973	1,189,789	1,501,572(2)	+16%
1972	1,006,143	1,310,134(2)	+ 8%
1971	928,185	1,238,000(3)	+24%
1970	751,291	1,002,000(3)	+37%
1969	549,933	733,000(3)	+26%
1968	437,498	583,000(3)	+52%
1967	287,058	383,000(3)	-

Sources:
(1) R.L. Polk Registration Data.
(2) Motorcycle Industry Council, "Manufacturer's Shipment Reporting System" (data representing most retail level sales were factored up by the share of new registrations represented by these sales.)
(3) These sales figures were estimated by assuming new motorcycle registrations in these years to be 75% of new motorcycles sold (based on 1972, 1973 relationships).



SOURCES:
1. 1972-1975 DATA: MOTORCYCLE INDUSTRY COUNCIL, "MANUFACTURER'S SHIPMENT REPORTING SYSTEM"
2. 1967-1971 DATA: ESTIMATES DERIVED FROM REGISTRATION DATA

FIGURE 8-1 NEW MOTORCYCLE SALES, 1967 - 1978



SOURCE: MOTORCYCLE INDUSTRY COUNCIL

FIGURE 8-2 U.S. NEW MOTORCYCLE REGISTRATIONS, 1967 - 1978

Table 8-2
MOTORCYCLE INDUSTRY COUNCIL MANUFACTURER'S SHIPMENT REPORT DEFINITIONS

MOTORCYCLE

A vehicle which is fully or partially propelled by a power source other than muscular power and designed to travel with no more than three wheels in contact with the ground.

INCLUDED IN THIS REPORT ARE:

- Two wheel motorcycles
- Motorcycles with side cars
- Three wheel motorcycles
- Mini-cycles
- Mini-bikes
- All-terrain two and three wheels
- Motorized bicycles
- Motor scooters
- Mopeds

SPECIFICALLY EXCLUDED FROM THIS REPORT ARE:

- Golf carts
- Tractors
- Equipment designed specifically for in-factory industrial uses
- Three wheel vehicles with a full passenger enclosure

SHIPMENTS

Net wholesale shipment of motorcycles from manufacturers or distributors to retail dealers. Returns and adjustments from original shipments should be deducted in the month they occur, not applied to the original month shipped.

PARTICIPATING MANUFACTURER

The motorcycle manufacturers or wholesale distributors who submit regular shipment reports. The initial participating manufacturers are American Honda, Kawasaki Motors, Harley-Davidson, and Norton Triumph. Additional participation by other manufacturers will be approved individually by the M.I.C. Board of Directors.

ENGINE TYPES

Two stroke cycle engine:

An engine which requires two strokes of the piston to complete one combustion sequence composed of intake, compression, combustion, and exhaust. The fuel/air mixture is ignited once for every crankshaft rotation.

Four stroke cycle engine:

An engine which requires four strokes of the piston to complete one combustion sequence composed of intake, compression, combustion, and exhaust. The fuel/air mixture is ignited once for every two crankshaft rotations.

Other:

All engines which do not fall into either of the above categories.

WHOLESALE PRICE

The lowest price at which the motorcycle model is normally sold to dealers f.o.b. point of manufacture or point of entry. This wholesale price would not consider such extraordinary items as discounts, special promotional allowances, rebates or other incentives.

RETAIL PRICE

The estimated retail value of a motorcycle model as published on manufacturer "suggested retail prices". If more than one regional price is published, this should be the lowest of the alternative retail prices and should not include items such as transportation charges, set-up charges, dealer preparation charges, taxes, etc.

MODEL TYPE

Street motorcycle:

A motorcycle which is certified by its manufacturer as being in compliance with the Federal Motor Vehicle Safety Standards, and is designed primarily for use of public roads.

Off-road motorcycle:

A motorcycle which is not certified by its manufacturer as being in compliance with the Federal Motor Vehicle Safety Standards.

Dual purpose motorcycle:

A motorcycle which is certified by its manufacturer as being in compliance with Federal Motor Vehicle Safety Standards, designed with the capability for use on public roads as well as off-road recreational use.

Table 8-3

MOTORCYCLE INDUSTRY COUNCIL MANUFACTURER'S SHIPMENT REPORTING SYSTEM CATEGORIES*

Function	Size (Engine Displacement)	Engine Type
Street	Under 50 cc	2-stroke
Dual Purpose	50 - 99 cc	4-stroke
Off-Road	100 - 169 cc	
	170 - 349 cc	
	350 - 449 cc	
	450 - 749 cc	
	750 - 899 cc	
	900 cc and above	

---

*Special categories were devised for purposes of this study, only. The normal reporting system has different size categories. The street and dual purpose categories correspond to the street-legal category used in the cost analysis. Size categories were selected to provide flexibility in the event different product categorizations were required for regulatory purposes and because it was desirable to evaluate economic impacts in each category.

Table 8-4

MOTORCYCLE MARKET SHARE, BY FUNCTION

	1974(%)	1975(%)	1976(%)	1977(%)	1978(%)
Street	40.8	47.4	46.7	52.5	49.5
Off-Road	20.3	26.6	24.8	26.8	33.4
Dual Purpose	38.9	26.0	28.5	20.7	17.1

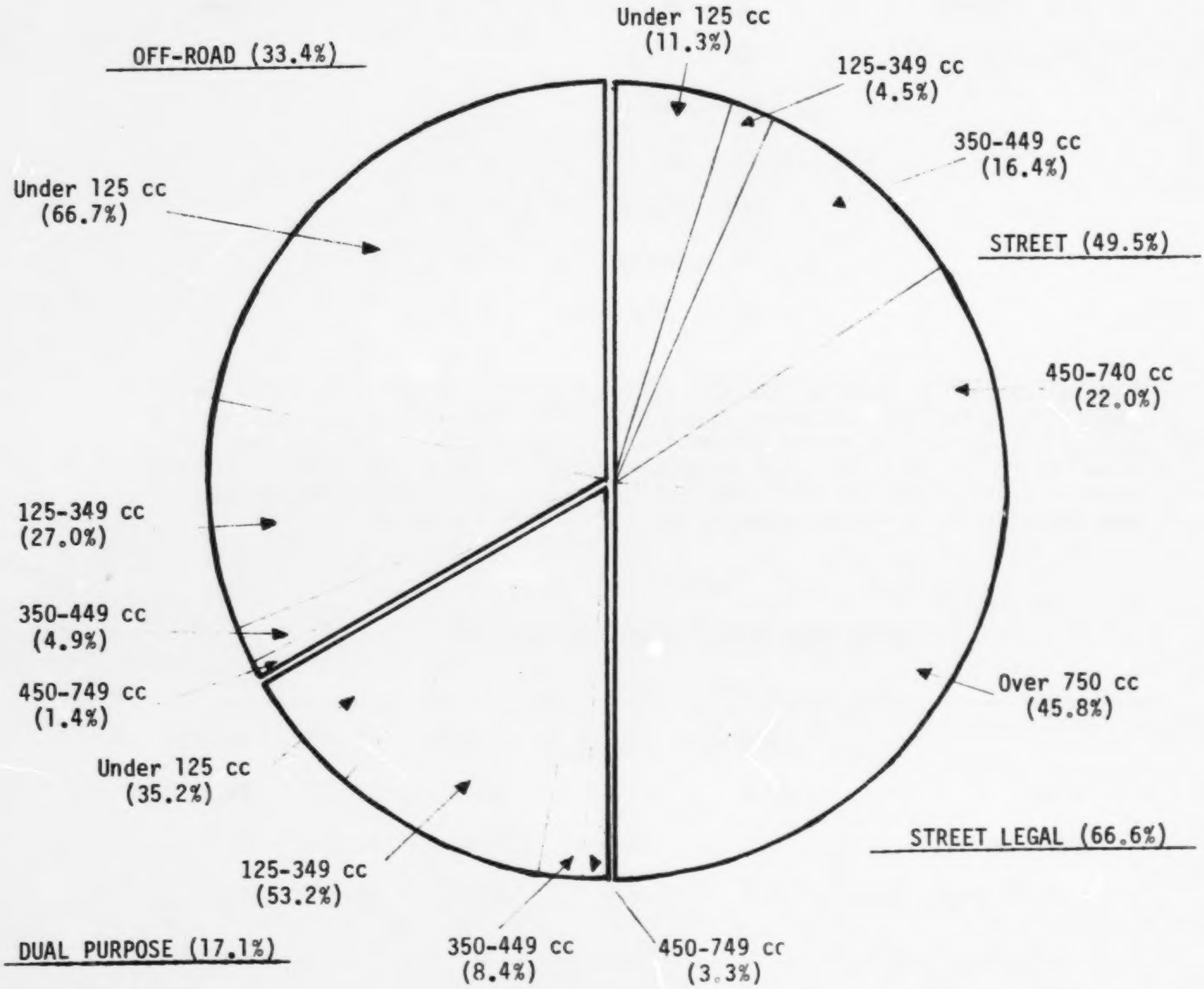


FIGURE 8-3 BREAKDOWN OF NEW MOTORCYCLE SALES BY PRODUCT CATEGORY: 1978

In the actual data base, there were no motorcycles in the following categories: any motorcycle under 50 cc; dual purpose motorcycles, 750 cc and above; and off-road motorcycles, 750 cc and above. In fact, there were very few off-road or dual purpose motorcycles 450 cc and above.

Total Street, Dual Purpose, and Off-Road Sales

New motorcycle sales data for total street, dual purpose, and off-road motorcycles in units and retail level dollars derived from the MIC Manufacturers Shipment Reporting System are summarized in Table 8-5.

Total motorcycle unit sales, (Table 8-5) including street, off-road and dual purpose models of all displacement classes, reached a peak of over 1.5 million units sold in 1973, generating gross revenues of $1.2 billion dollars, figures which, even discounting the effects of the 1974-1975 recession, have steadily declined from 1973 to 1978. However, while the unit volume of annual motorcycle sales in 1978 has declined by one-third since 1973, revenue in real terms has declined by only 17 percent. This is accounted for by the 25 percent increase in the real average price of motorcycles during this period.

Of the three functional forms of motorcycles (street, off-road, and dual purpose), unit sales of dual purpose motorcycles declined the most, from 550,000 in 1973 to 171,000, in 1978. The real average price of dual purpose motorcycles actually declined by 2 percent over that period. The demand for off-road motorcycles, while experiencing price increases roughly equivalent to the average, has remained fairly steady from 1973-1978; that of street motorcycles has declined approximately 20 percent while their average nominal price has almost doubled. Apparently, a shift in tastes has occurred, away from the more clumsy, yet versatile, dual purpose motorcycles, toward the specialized dirt motorcycles for off-road use and also toward street bikes. Thus the relative market shares of the three functional motorcycles have changed significantly over this period: street, from 43 percent to 50 percent off-road from 20 percent to 33 percent and dual purpose, from 37 percent to 17 percent.

Street Motorcycle Sales by Engine Displacement Class

While total street motorcycle unit sales declined from 554,000 units to 494,000 over the period 1972 to 1978 (Table 8-5), there were significant changes in the market shares of the various displacement classes during this period (See Table 8-6). The shares of motorcycles in the 125 to 349 cc, 350 to 449 cc, and 450 to 749 cc displacement classes all declined, although the largest of these, the 450 to 749 cc group, declined the least. The market share of motorcycles under 125 cc increased dramatically from 1.3 percentin 1974 to 11.3 percent in 1978, and the share of the sales of motorcycles over 750 cc increased from 28.4 percent in 1974 to 45.8 percent in 1978. Analagous to the move away from dual purpose motorcycles to either specifically street or off-road motorcycles appears to be a movement away from medium displacement motorcycles, 125 to 749 cc (which comprise only 42.9 percent of the market), toward motorcycles that are very large or very small and are suited to more specific purposes.

Table 8-5

NEW MOTORCYCLE SALES DATA FOR TOTAL, STREET, DUAL PURPOSE, AND OFF-ROAD CATEGORIES (1972-1978)

TOTAL	1972	1973	1974	1975	1976	1977	1978
New Motorcycle Sales (Thousands of Units)	1,310	1,501	1,181	830	1,049	1,077	998
Average Retail Price (1) (Dollars)	756	814	1,095	1,278	1,236	1,321	1,492
New Motorcycle Sales (Millions of Dollars)	991	1,221	1,293	1,125	1,298	1,423	1,489
STREET							
New Motorcycle Sales (Thousands of Units)	554	647	482	422	490	565	494
Average Retail Price (Dollars)	1,048	1,087	1,546	1,805	1,738	1,794	2,086
New Motorcycle Sales (Millions of Dollars)	570	703	745	762	852	1,015	1,030
DUAL PURPOSE							
New Motorcycle Sales (Thousands of Units)	541	550	459	226	299	223	171
Average Retail Price (Dollars)	598	639	819	834	819	815	907
New Motorcycle Sales (Millions of Dollars)	323	352	376	183	245	182	155
OFF-ROAD							
New Motorcycle Sales (Thousands of Units)	225	304	240	232	260	289	333
Average Retail Price (Dollars)	434	545	717	758	771	783	913
New Motorcycle Sales (Millions of Dollars	98	166	172	175	201	226	304

(1) Discrepancies in 1973-1975 data due to derivation technique used on monthly data series.

Source: Motorcycle Industry Council, "Manufacturers Shipment Reporting System" (Data representing retail level sales in units and dollars factored upward to derive data shown in table).

Dual Purpose Motorcycle Sales by Displacement Class

All categories of dual purpose motorcycles (Table 8-5) showed dramatic declines in unit sales between 1974 and 1978 with corresponding declines in total dollar sales. The market for dual purpose motorcycles is dominated by those under 350 cc engine displacement (i.e., those under 125 cc and those between 125 and 349 cc). Throughout the period these two classes together comprised between 84 percent and 89 percent of all dual purpose motorcycles (See Table 8-7). As a result, with total dual purpose motorcycle sales falling in 1978 to one-third of their 1973-1974 level (Table 8-5), these two classes each suffered declines in unit sales proportionately greater than the same engine displacement classes in any other motorcycle category: street, or off-road. However, the market shares within the dual purpose motorcycle category did not shift substantially.

Off-Road Motorcycle Sales by Engine Displacement Class

Historically, total unit sales of off-road motorcycles have held fairly steady over the 1974-1978 period (see Table 8-5). Revenues, however, have almost doubled due to the increases in the average unit price of off-road motorcycles, from $545 in 1973 to $913 in 1978 (see Table 8-5). Traditionally, the majority of off-road unit sales have been attributed to the less than 125 cc and 125 to 349 cc classes (see Table 8-8). Like dual purpose motorcycles, market shares within the off-road motorcycle category did not shift substantially over the period.

Demographic Developments

Males of all ages constitute approximately 90 percent of all motorcycle owners (see Table 8-9), although most owners were males between 20 and 34 years of age. The relevant demographic group for analysis of buyer behavior is the number of males with income in this age group.

Over the period 1973 to 1977, the growth rate for the number of males with income, for the most part, declined. Thus, the effective demographic market for motorcycle sales was impaired over this period. Table 8-10 provides the percentage changes in the number of males with income in the age groups 20 to 24 and 25 to 34 years. The large age group, males 25 to 34 years, suffered declining rates of growth in 1974, 1975 and 1977. The age group 20 to 24 years decreased sharply in 1975 and 1977. The long-term growth potential for motorcycle sales may be constrained by the growth rates in these effective population age groups unless there is a structural shift in the buying patterns of other age/sex groups.

Real Income Trends

While the real disposable income for the U.S. recovered from its decline after 1974, the real mean income of the effective market for motorcycles males of ages 20 to 34, continued to decline, although at a slower rate, through 1975. This age group, traditionally more seriously affected by

Table 8-6

STREET MOTORCYCLE MARKET SHARE BY ENGINE DISPLACEMENT CLASS

	1974(%)	1975(%)	1976(%)	1977(%)	1978(%)
Less than 125 cc	1.3	2.2	5.9	9.0	11.3
125 - 349 cc	12.8	10.1	8.1	8.6	4.5
350 - 449 cc	31.9	26.1	31.1	21.3	16.4
450 - 749 cc	25.6	24.0	20.1	21.9	22.0
750 cc. or greater	28.4	37.6	34.8	39.2	45.8

Table 8-7

DUAL PURPOSE MOTORCYCLE MARKET SHARE BY ENGINE DISPLACEMENT CLASS

	1974(%)	1975(%)	1976(%)	1977(%)	1978(%)
Less than 125 cc	31.8	36.2	33.5	35.7	35.1
125 - 349 cc	57.8	50.7	54.0	49.1	53.2
350 - 449 cc	10.1	12.6	10.1	11.2	8.4
450 - 749 cc	.3	.5	2.4	4.0	3.3

Table 8-8

OFF-ROAD MOTORCYCLE MARKET SHARE BY ENGINE DISPLACEMENT CLASS

	1974(%)	1975(%)	1976(%)	1977(%)	1978(%)
Less than 125 cc	59.2	55.8	56.2	58.8	66.7
125 - 349 cc	33.2	36.0	36.0	34.0	27.0
350 - 449 cc	5.2	6.6	5.6	4.9	4.9
450 - 749 cc	2.4	1.6	2.2	2.3	1.4

Table 8-9

MOTORCYCLE BUYER'S DEMOGRAPHIC PROFILE

Sex	All Owners
Male	91%
Female	9%

Age	
Under 16 years	13%
16 - 17 years	10%
18 - 20 years	13%
21 - 24 years	15%
25 - 29 years	15%
30 - 39 years	19%
40 - 49 years	10%
	4%
	1%
	100%
Median age	24 yrs.

Marital Status	All Owners
Married	49%
Single	48%
Widowed/Divorced	2%
Undesignated	1%
Total	100%

Education	
8th grade or less	10%
High school incomplete	24%
High school graduate	33%
College incomplete	20%
College graduate	11%
Undesignated	2%
Total	100%

Source: Gallup Organization, "Survey of Motorcycle Ownership, Usage, and Maintenance".

Table 8-10

AGE GROUP PERCENT CHANGE IN THE NUMBER OF MALES WITH INCOME

	1973	1974	1975	1976	1977
Males, 20-24	2.46	3.17	.96	3.21	1.48
Males, 25-34	4.60	3.83	3.16	3.81	2.49

downturns in the economy than older age groups, suffered declines in real mean income of 4.6 and 3.4 percent in 1974 and 1975, respectively (see Table 8-11). The real earning power of the age group 20 to 34 years did not fully recover in 1976 and 1977, when total real disposable income had been growing at the rate of 3.7 percent per year. The real income of potential motorcycle buyers decreased 8 percent during 1974 and 1975, while having increased by only 2 percent during 1976 and 1977. Thus, with a declining rate of growth in the number of potential buyers and an absolute decline in the real incomes of this group, the market environment for motorcycle sales has not been improving.

Price Trends

The average unit price of motorcycles increased from $814 in 1973 to $1,492 in 1978, or by 83.3 percent (Table 8-5). During the same period, the price of all other goods competing for the consumer's budget, as measured by the Consumer Price Index, increased by 32.2 percent. Thus the relative price of motorcycles, compared with all other commodities, increased almost three times as fast during those five years. Only in 1976 was the situation somewhat ameliorated, with the real price of motorcycles declining by approximately 8.5 percent (see Table 8-12 for a comparison of percent changes in the average unit price of motorcycles and the consumer price index).

With a deteriorating effective purchasing power base for motorcycle sales and a substantial increase in the real price of motorcycles, the decline in motorcycle sales over the period 1973 to 1978 is understandable.

8.1.3 Baseline Forecast of New Motorcycle Sales

The analysis of the market environment for motorcycles and the price of motorcycles (and prices of other products) over the period 1973 to 1975 provided the approach for statistically modeling the determinants of demand for unit motorcycle sales. The basis of the demand model used in the EPA analysis was a sales-adjustment equation, which related sales of each period to sales in the previous period. Statistical equations were estimated econometrically by relating unit motorcycle sales (by type and function) to sales in the previous period and to demographic, income, price, and motorcycle characteristics over the period 1973 to 1975. With these equations the forecasts of unit sales and revenues (given prices) for each class of motorcycle were generated. A more detailed description of this model is in Appendix F.

The annual forecasts of the demand model, based on the monthly projections starting in January, 1979, are depicted in Figures 8-4 through 8-8. By 1990, (Figure 8-4a) total unit motorcycle sales will be only 45.5 percent greater than in 1973 (Table 8-1). Furthermore, despite the impressive gains for motorcycle sales forecast for 1979 and 1980, the 1973 level (Table 8-1) of 1.5 million units will not be reached until 1982. With the assumption that average unit motorcycle prices will increase by 7 percent per year, total motorcycle revenues will have doubled between 1978 ($1.5 billion) and 1981

Table 8-11

PERCENT CHANGE IN REAL INCOME OF MOTORCYCLE BUYERS

	1974	1975	1976	1977
Disposable Income for the U.S.	-1.8	+0.8	+3.7	+3.7
Mean Income, Males, 20 to 34 years	-4.6	-3.4	+1.0	+1.0

Table 8-12

PERCENT CHANGES IN THE AVERAGE UNIT PRICE OF MOTORCYCLES AND THE CONSUMER PRICE INDEX

	1974	1975	1976	1978
Average Unit Price of Motorcycles	+36.3	+16.1	-2.9	+8.4
Consumer Price Index	+11.1	+ 9.2	+5.8	+7.6

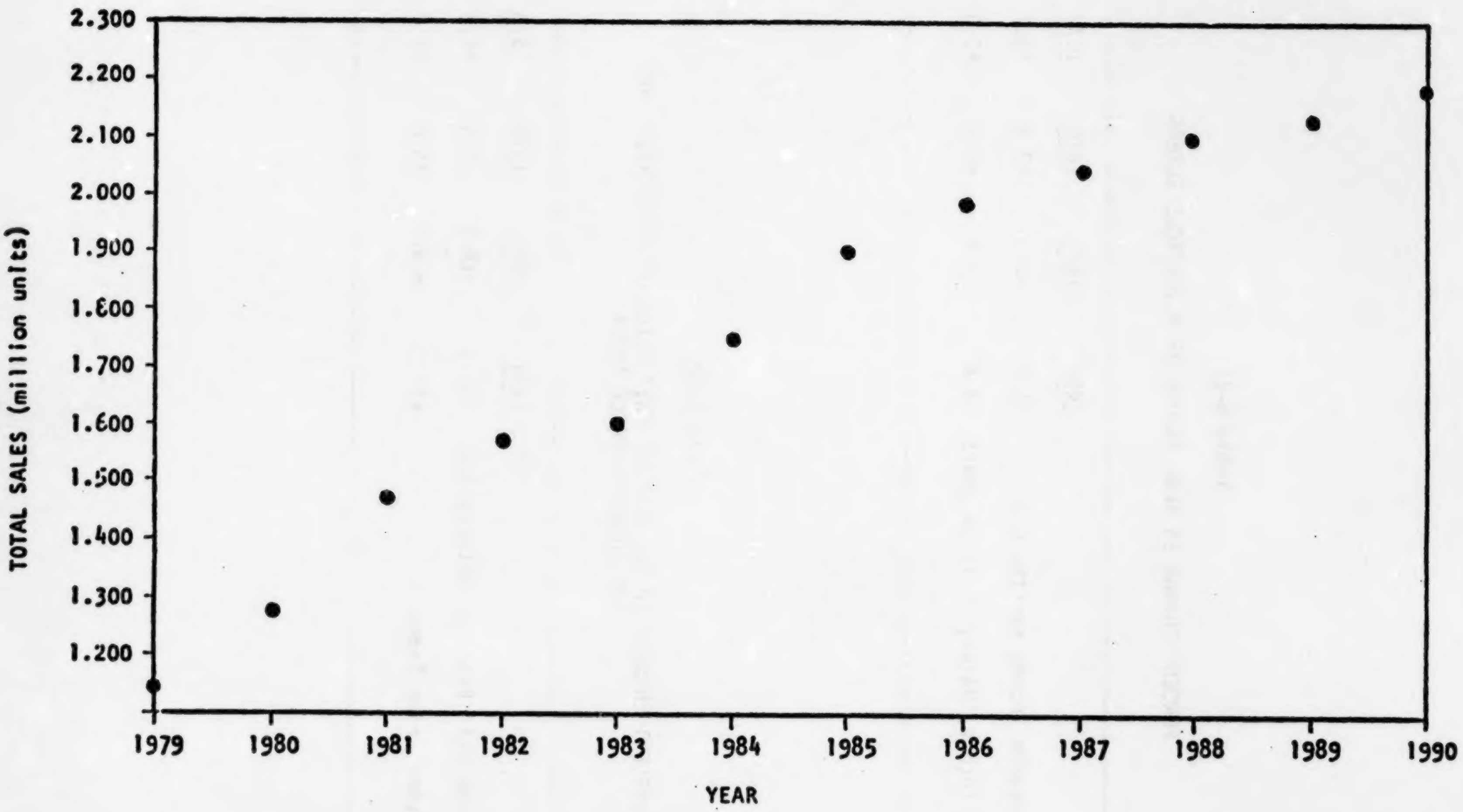


FIGURE 8-4a. PROJECTED TOTAL UNIT SALES

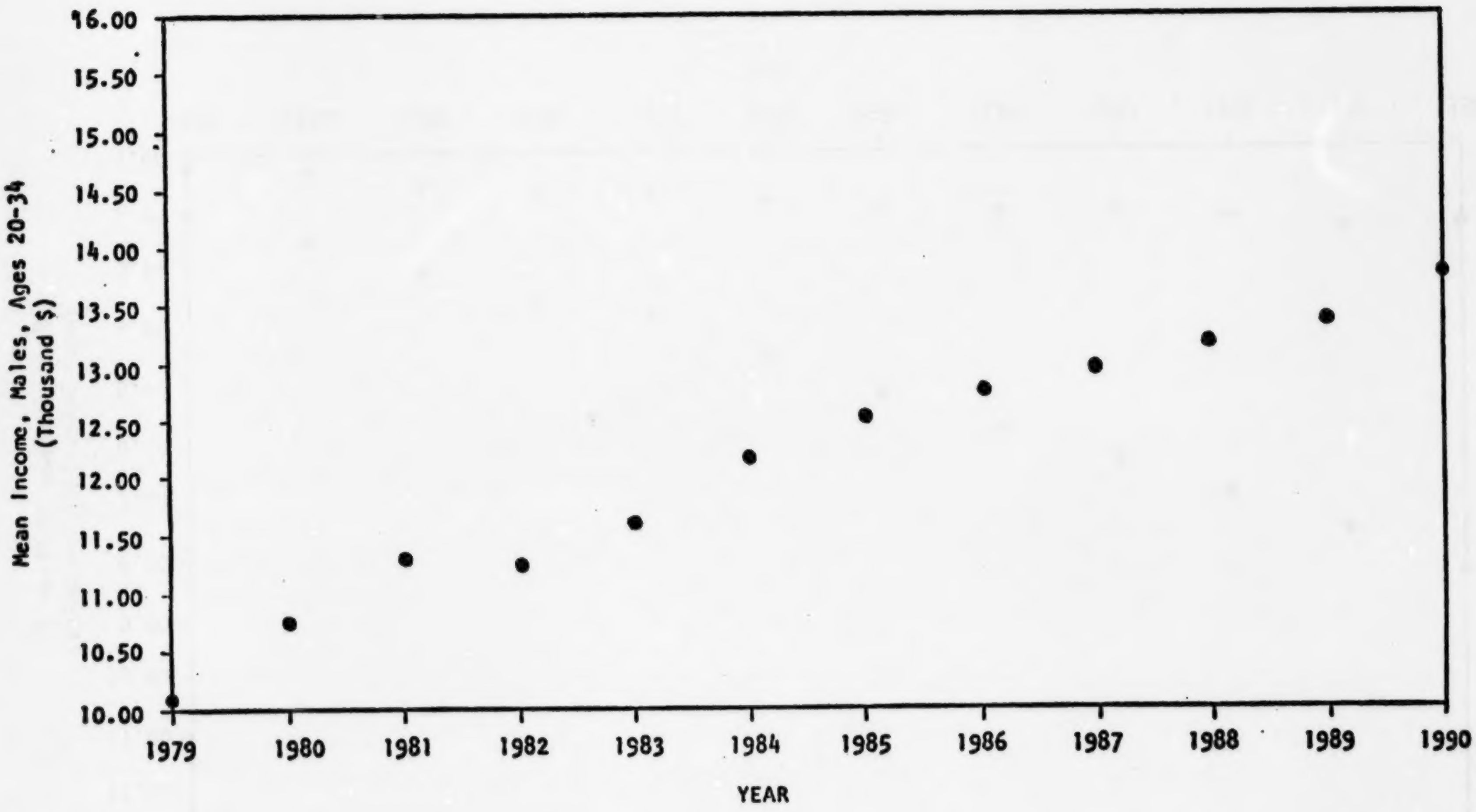


FIGURE 8-4b. PROJECTED MEAN INCOME, MALES, AGES 20-34

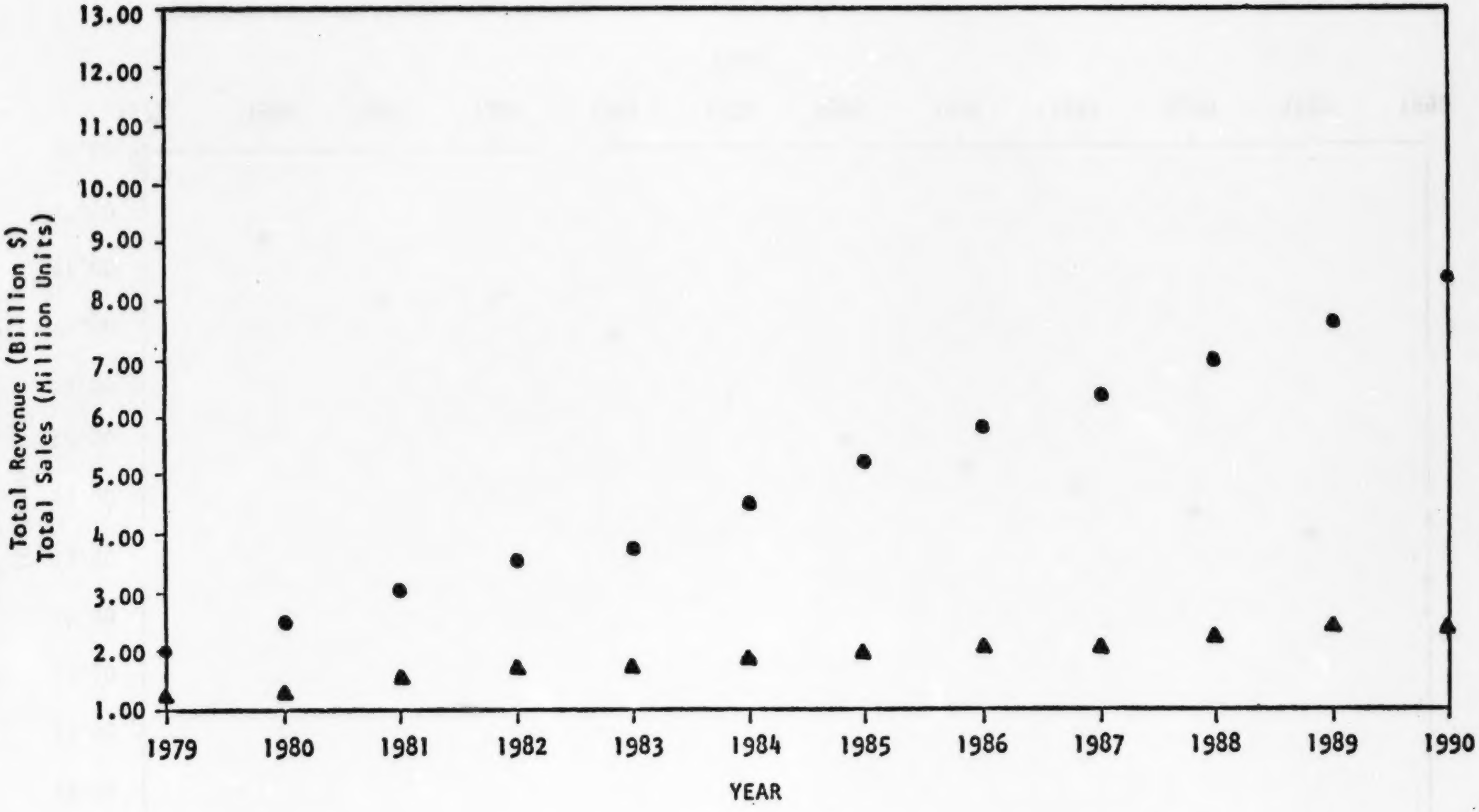


FIGURE 8-5. PROJECTED TOTAL REVENUE VS. TOTAL UNIT SALES

● = Total Revenue (billion $)
▲ = Total Sales (million units)

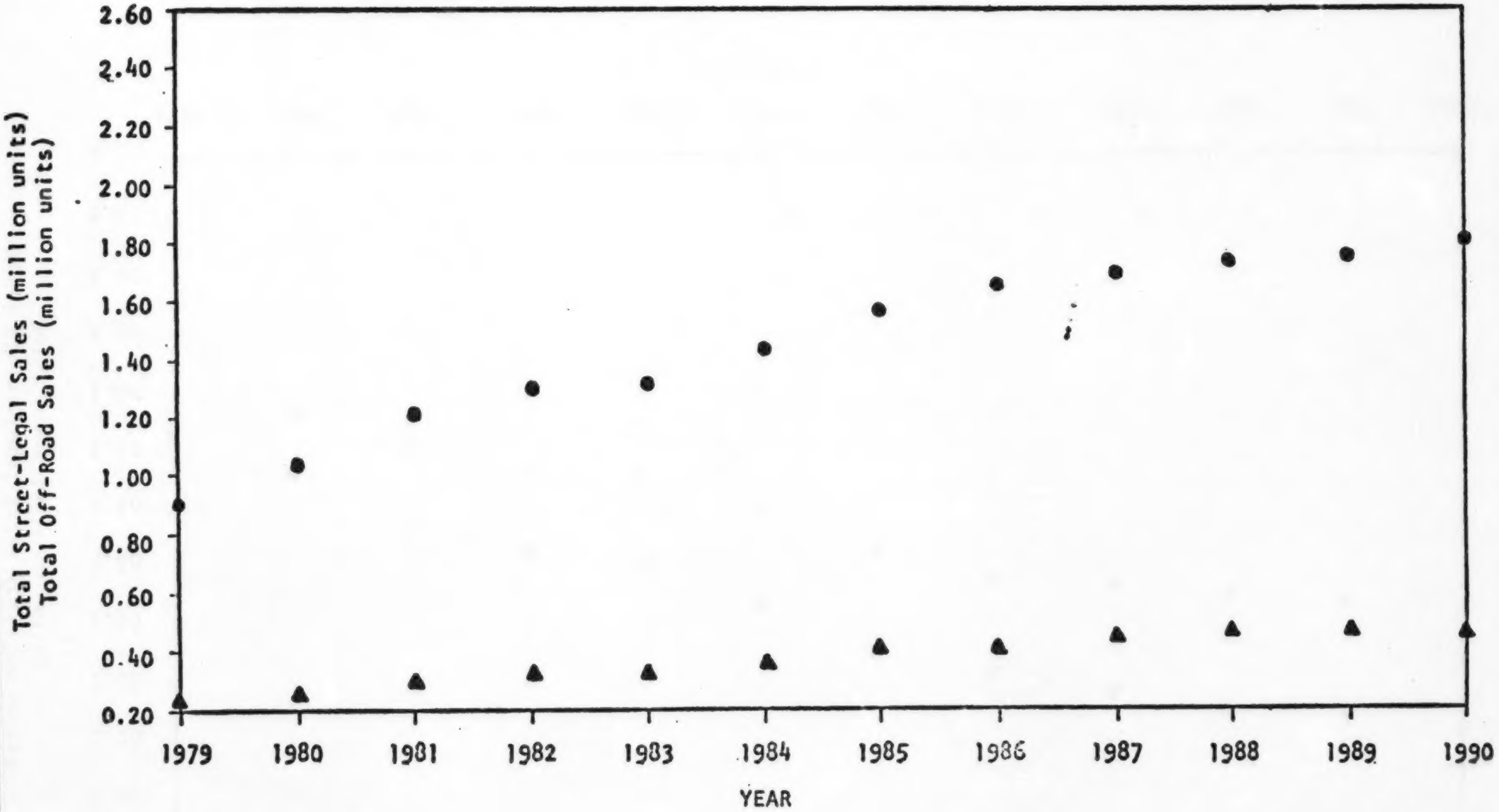


FIGURE 8-6. PROJECTED STREET AND OFF-ROAD SALES

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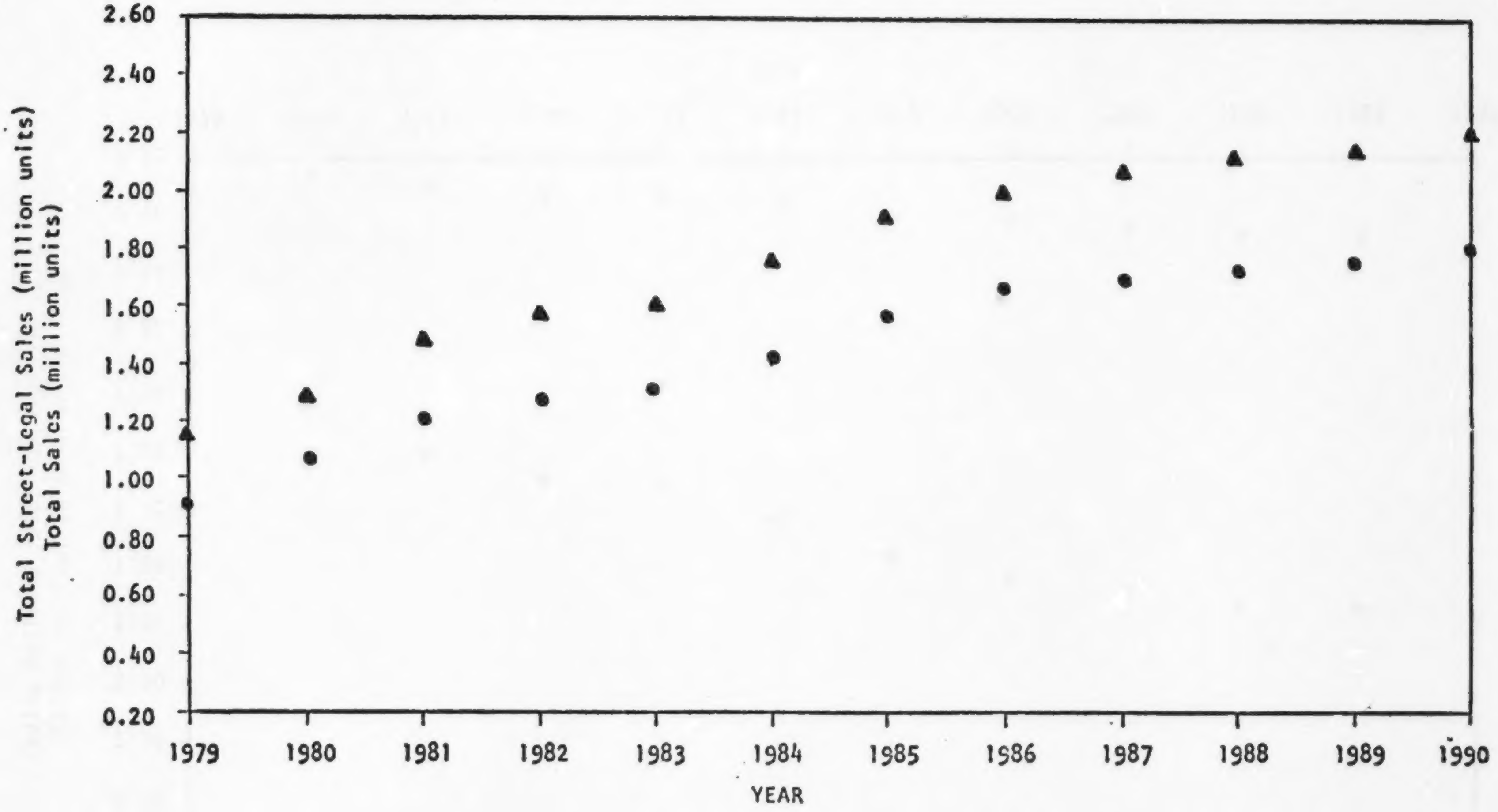

FIGURE 8-7. PROJECTED STREET- LEGAL VS. TOTAL UNIT SALES

● = Total Street-Legal Sales (million units)
▲ = Total Sales (million units)

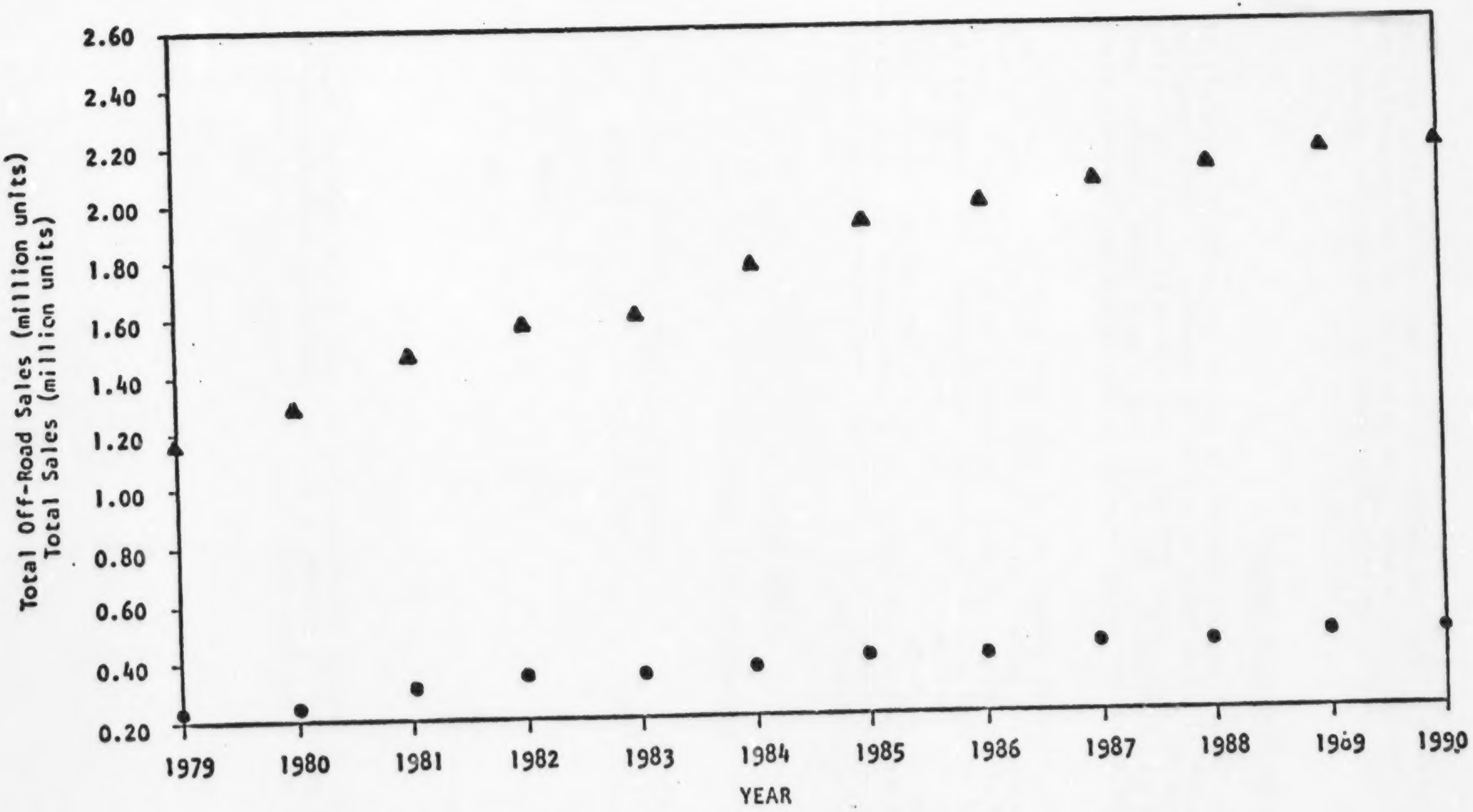

FIGURE 8-8. PROJECTED OFF-ROAD UNIT SALES VS. TOTAL UNIT SALES

● = Total Off-Road Sales (million units)
▲ = Total Sales (million units)

($3.0 billion). By 1990 (Figure 8-5), the total motorcycle market is expected to reach $8.3 billion. For the purpose of the baseline forecast, EPA has assumed an annual growth rate in unit motorcycle sales of two percent for the years 1991 to 2000. After the year 2000, motorcycle sales are assumed to remain constant.

8.2 Impact on New Motorcycle Demand

The primary impact on the demand for new motorcycles as a result of the implementation of regulatory standards is expected to be a reduction in demand caused by unit price increases that are attributable to meeting the specific noise standards.* The motorcycle demand model described previously was used to relate demand impacts to the unit price increases shown in Section 7.

Price elasticities of demand, as derived from the historical data base, are shown in Table 8-13 below. The elasticities were calculated at the mean of the independent variable. It should be noted that the structural form of the demand equation does not yield constant elasticities. (The slope of the demand curve is the invariant in the demand model; i.e., the ratio of the change in demand to a change in price.) For the forecast period 1979-1990, the composite price elasticity of demand for all motorcycles was approximately -1.1, with price elasticities for street and off-road motorcycles of approximately -1.2 and -.75, respectively.

Table 8-13

MOTORCYCLE PRICE ELASTICITY

Displacement Class	Motorcycle Category Street	Dual Purpose	Off-Road
Below 100 cc	-.928	-.867	-.953
100-169 cc	-.935	-.997	
170-349 cc	-.967	-.74	-1.148
350-749 cc	-.836	-.912	
750 cc and above	-.768	-.45	

---

*Potential shifts in demand, not calculated as part of the economic impact analysis, might be caused by changes in styling, safety and performance which are required to meet a mandated noise level.

Table 8-14

MOTORCYCLE NOISE EMISSION STUDY LEVELS AND EFFECTIVE DATES

Date	Regulatory Level (SAE J331a)
January, 1981	83 dB
January, 1983	80 dB
January, 1986	78 dB
January, 1990	75 dB

Four regulatory levels effective on the dates shown in Table 8-14 were studied. The noise standards used in this analysis are expressed in not-to-exceed levels. Based on available data for each regulatory level, manufacturers must design their products to meet a level 2 to 3 dB less than the noise standard to allow for production and testing variabilities. Throughout the analysis, this level will be called "design level".

Estimates of reductions in demand are summarized in Table 8-15, for both nominal and worst cases. Relative reductions in unit demand from a baseline forecast are shown in order to express the reduction in real terms. A decrease in motorcycle demand is projected because of the negative price elasticities for motorcycles that may result from increases in retail prices which can be attributed to noise control. The projected reductions for each study level that was analyzed are shown in Figure 8-10. The data indicate that signficant reductions in demand are expected for noise emission standards lower than 80 dB (SAE J331a).

The impact of each standard is discussed in detail below.

83 dB Regulatory Level, 1981

The baseline demand forecast for all new motorcycles in 1981 is 1,467,000 units, broken down as follows: 1,165,000 street motorcycles, and 302,000 off-road motorcycles. An 83 dB regulatory level in 1981 (SAE J331a) is expected to reduce demand by 0.4 percent in both the nominal case and the worst case.

80 dB Regulatory Level, 1983

This standard is expected to reduce demand by 2.1 percent in the nominal case and by 5.1 percent in the worst case. The product category with the largest potential impact is street motorcycles under 350-449 cc. Reduction in demand is expected to be at least 2.5 percent in the nominal case and 6.8 percent in the worst case for this product category.

Table 8-15

ESTIMATED RELATIVE REDUCTION IN DEMAND FOR NEW MOTORCYCLES
DUE TO NOISE CONTROL REGULATIONS
FIRST YEAR FOR EACH STANDARD

		RELATIVE REDUCTION IN DEMAND (%)		
CATEGORY YEAR	1981	1983	1986	1990
Regulatory Level*	83 dB	80 dB	78 dB	75dB**
Nominal (Expected) Case				
Street-Legal***	0.3	2.0	5.4	14.4
350-449 cc	0.4	2.5	6.7	14.7
450-749 cc	0.3	1.5	4.4	9.6
750 cc and above	0.2	0.9	2.5	4.6
Off-Road	0.7	2.7	5.2	
All Motorcycles	0.4	2.1	5.4	
Worst Case				
Street Legal**	0.4	5.1	10.0	18.6
350-449 cc	0.5	6.8	12.8	18.6
450-749 cc	0.3	4.4	8.3	12.1
750 cc and above	0.2	2.3	4.4	5.8
Off-Road	0.8		7.7	
All Motorcycles	0.4	5.1	9.5	

---

*Not to exceed regulatory level (SAE J331a).

**Cost figures for 75 dB available only for street motorcycles.

***Categories under 350 cc are excluded here since these categories cannot be forecasted; i.e., the categories of engine size routinely collected by the Motorcycle Industry Council do not match the categories for which the demand equations were estimated.

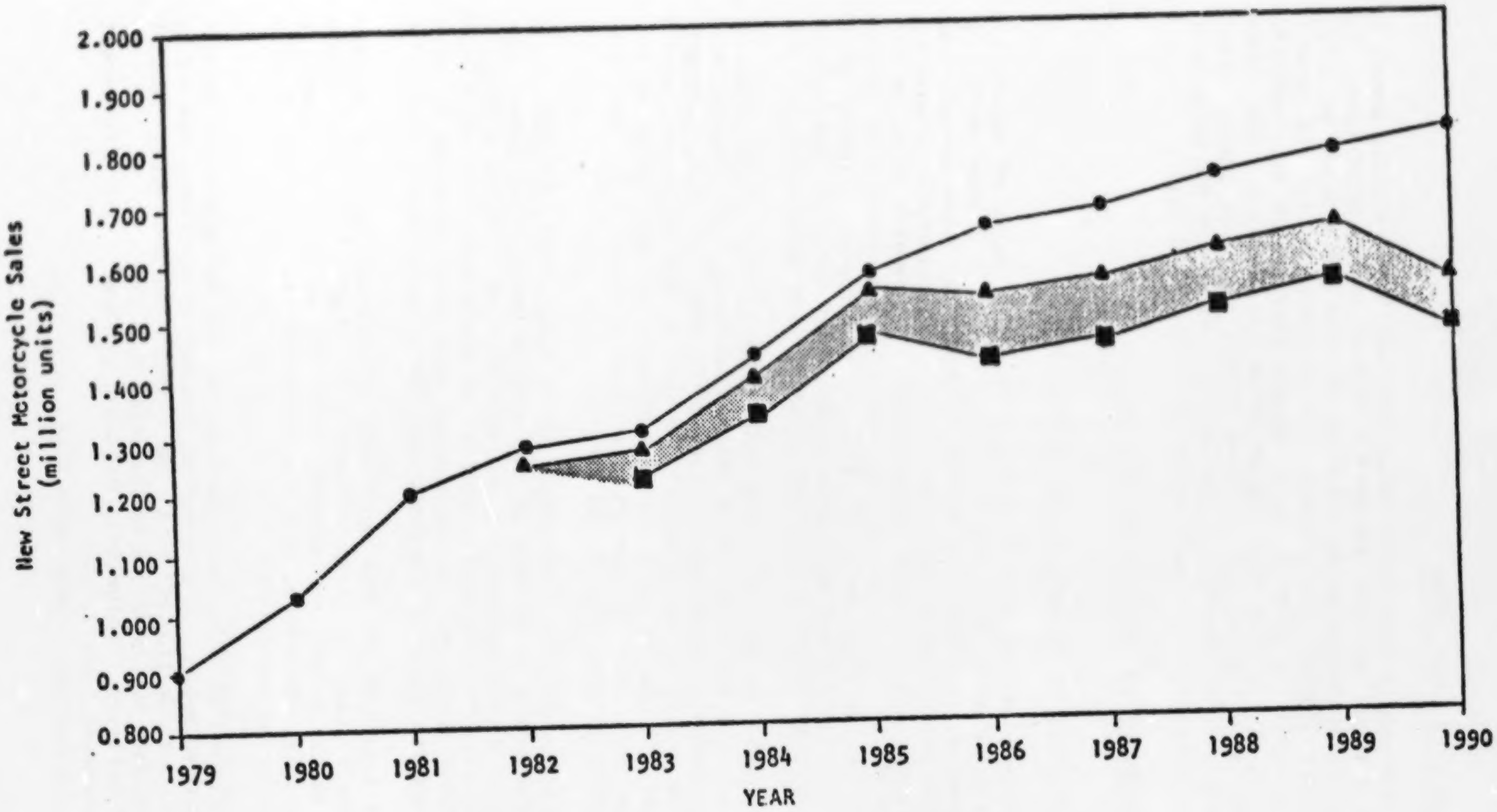

FIGURE 8-10. ESTIMATED REDUCTION IN DEMAND FOR NEW STREET-LEGAL MOTORCYCLES DUE TO NOISE REGULATIONS

● = Base Case
▲ = Nominal Case
■ = Worse Case (Shaded area indicates nominal and worst case bounds)

78 dB Regulatory Level, 1986

A 78 dB standard in 1986 could reduce the baseline forecasted demand by 5.4 percent in the nominal case and by 9.5 percent in the worst case. The product categories projected to be affected the most would again be street motorcycles under 350-449 cc. Motorcycles in these categories experience the greatest relative price increase, because they are the most sensitive to price changes; i.e., they have larger price elasticities. The street motorcycles, 750 cc and above, are expected to have the least severe impact: 2.5 percent reduction in the nominal case and 4.4 percent in the worst case. This motorcycle category is the least sensitive to price increases.

8.3 Impacts on Demand for Products and Services

8.3.1 Historical Aftermarket Sales and Forecasts

The motorcycle aftermarket industry represents sales of motorcycle replacement parts, accessories, apparel, and services. A broader definition of the aftermarket would include motorcycle insurance and miscellaneous items such as consumer publications, and advertising. The motorcycle aftermarket industry has experienced extremely rapid growth. Aftermarket sales in 1975 were estimated* at $1.8 billion, an increase of approximately 20 percent over 1974. For the two years prior to 1974, sales increased an average of 40 percent per year, the market more than doubled between 1972 and 1975.** Table 8-16 provides estimated aftermarket sales for the period 1972 to 1975.

The aftermarket industry is being stimulated by the growing base of motorcycle owners, improved advertising and merchandising, new products, more affluent riders, and the trend toward using motorcycles for basic transportation. With the growth of the motorcycle population, one of the most useful ways to consider aftermarket sales is expenditures per motorcycle in use. Expenditures per motorcycle in use as displayed in Table 8-16, have been growing at the rate of approximately 20% per year.

A Ziff-Davis motorcycle aftermarket survey taken early in 1975 indicated that approximately 85 percent of all motorcycle/minicycle owners purchased replacement parts, accessories, and apparel items from the motorcycle aftermarket industry.*** Twenty-two percent of these consumers spent more than $100 for their purchases. On the average, each owner spent $86 for such items as: replacement parts and accessories ($54), and clothing ($32).****

A detailed breakdown of 1974 motorcycle aftermarket sales, as derived from the Ziff-Davis Study, is shown in Table 8-17. Each of the major components of aftermarket sales, replacement parts and accessories, apparel, service and repairs, insurance, and miscellaneous, is described in more detail in the following paragraphs.

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* Data for aftermarket sales and growth trends are approximations because the an organized motorcycle aftermarket industry is relatively new and no organized data collection effort by the industry has been made. Most of the detailed data available are for calendar year 1974.

** Frost and Sullivan, "Motorcycle Original Equipment and Aftermarket Study Announcement," April, 1975.

*** Ziff-Davis Publications, "Motorcycle Aftermarket Study," 1975.

**** Ibid.

Table 8-16

AFTERMARKET SALES GROWTH*

Year	Aftermarket Sales (Millions of $)	Percentage Increase	Total Number of Motorcycles in Use (Millions of Units)	Aftermarket Sales per Motorcycle In Use
1972	$ 764	-	5.4	$ 141
1973	$ 1,070 (1)	40%	6.2	$ 173
1974	$ 1,500	40%	7.1	$ 211
1975	$ 1,810 (2)	20% (2)	7.2 (3)	$ 251 (3)

Sources:
1. The 1974 data point obtained from Ziff-Davis Publishing Company, "Motorcycle Aftermarket Study".
2. Estimates provided by Motorcycle Dealer News.
3. Estimates derived from EPA's forecast model of the motorcycle stock.

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* Data for aftermarket sales and growth trends are approximations because the an organized motorcycle aftermarket industry is relatively new and no organized data collection effort by the industry has been made. Most of the detailed data available are for calendar year 1974.

Table 8-17

MOTORCYCLE INDUSTRY AFTERMARKET SALES, 1974

Item	1974 Annual Sales (Millions of Dollars)	
Replacement Parts and Accessory Items		400
Air Filters	5.9	
Brake/Clutch Levers	9.7	
Cables	12.1	
Cafe Racing Kits	4.1	
Carburetors	8.7	
Chain Lubricants	7.9	
Cleaners and Waxes	3.8	
Custom Seat	12.9	
Drive Chain	18.1	
Exhaust System Products	30.6	
Fairings	29.2	
Fenders	6.6	
Gas Tank	9.0	
Hop-Up Kit	11.2	
Lubricants (other than chain)	14.1	
Luggage Rack	13.5	
Mirrors	5.8	
Replacement Tires	55.6	
Saddle Bags and Tote Boxes	12.0	
Shock Absorbers	6.8	
Side Cars	14.7	
Sissy Bars	16.4	
Spark Plugs	24.6	
Specialty Wheels	13.4	
Sprockets	16.7	
Tools	31.4	
Windshields	5.2	
Apparel		223
Service Receipts/Repair		450
Insurance		385
Miscellaneous (Consumer Publications, etc.)*		50
	Total	1,508

Source: Ziff-Davis Publications Motorcycle Aftermarket Survey

* Energy and Environmental Analysis, Inc., "Economic Assessment of Motorcycle Exhaust Emission Regulations".

Apparel

Sales of apparel (including helmets) were estimated to be over $200 million in 1974. The same manufacturers, distributors, and retail outlets that are affected by changes in the market for replacement parts and accessories will be affected by changes in the market for apparel.

Service/Repairs

Service and repair receipts totaled an estimated $450 million in 1974. Service revenues are increasing principally because of the larger population of motorcycles in use. Service receipts primarily affect dealers, since on the average these receipts comprise 15 percent of each dealer's revenue.

Insurance

Motorcycle owners paid an estimated $385 million for insurance premiums in 1974. Average premiums generally vary with motorcycle size. Changes in the demand for motorcycle insurance will have very little effect on the motorized vehicle insurance industry, since motorcycles are a very small proportion of total underwriting. However, there are a few companies that specialize in motorcycle insurance and these companies will be significantly affected by actions affecting motorcycle insurance revenues.

Miscellaneous

Miscellaneous includes revenues from motorcycle publications, books, schools and consultants.

Replacement Parts and Accessories

The market for parts and accessories in 1974 was estimated at $400 million, which represented approximately 27 percent of aftermarket sales. Aftermarket items are generally purchased for performance, styling, functional or maintenance purposes. Exhaust system products, mechanical products, mechanical parts and hop-up kits are big sellers in this category. Sales of styling/functional items such as fairings, windshields, saddle bags and tote-boxes that appeal to riders of large street touring motorcycles are increasing significantly as a result of the increased growth of these types of motorcycles. Any change in the demand for replacement parts and accessories will directly affect aftermarket manufacturers, distributors and retail outlets such as dealers, accessory shops,discount stores and mail order firms.

Exhaust System Sales

Sales for exhaust system products, which were $30.6 million in 1974, will be particularly impacted by the motorcycle noise control standards. Results of a survey from Ziff-Davis publications for exhaust system purchases by motorcycle owners in 1974 are shown in Table 8-18. These data indicate that 616,000 buyers (8.7 percent of all motorcycle owners) purchased 1.4 exhaust system products (mufflers, expansion chambers, etc.) each, and spent an average of $50 for each purchase, or $35 per unit. Most of the exhaust system products (63.5 percent) were purchased from dealers. For forecasting purposes, the most feasible way to consider exhaust system sales is to relate those sales to the number of motorcycle in use (the stock of motorcycles). For 1974, and average .1214 exhaust systems were sold per motorcycle in use. Using this relationship and forecasts of the population of motorcycles, as derived using Motorcycle Industry Council scrappage rates* and new motorcycle sales projections, forecasts of exhaust system sales (in units) were developed. These forecasts are shown in Table 8-19.

8.4 Total Annualized Costs

Increases in purchase prices and operation and maintenance costs for each of the regulatory study levels (Table 8-21) will costs attributable to noise control. Purchase price increases are incurred at the time of sale, and operation and maintenance costs are incurred annually for the life of the product.

To compare regulatory options (See Table 8-21) for a given product and between products, it is necessary to use a statistical metric to characterize this cost stream. The statistical metric used for all new product noise regulations is "uniform annualized costs", or more simply, annualized costs.

A cost stream over a given period is represented by a uniform cost stream (annual costs of equal dollar amount) that has the same present value. That is, the cost stream to be represented is converted to a present value using a specified time value of money. This present value is converted to a cash stream of equal units, which, using the same time value of money, has the same present value. In essence, a cost stream over a given period is converted to an annuity over that same period. This statistical metric accounts both for the size and timing of costs incurred. The individual purchase price in creases developed in the previous sections were used to calculate total purchase price increases in each year based on specific not-to-exceed study levels and effective dates. The number of units sold in each year was adjusted by the expected decrease in demand calculated in Section 8.2. Increased purchase prices were converted to 1978 dollars. Similarly, the increased operation and maintenance costs that were developed were applied to the stock of vehicles in any year (adjusted for decreased demand), and expressed in 1978 dollars.

8.4.1 Vehicle Annualized Costs

Table 8-21 shows the regulatory study levels used in computing annualized costs. Four street and four off-road regulatory options were assessed.

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*The Motorcycle Industry Council's estimates of "survival" rates for motorcycles over time is reproduced in Table 8-20. The scrappage rate is equal to one minus the survival rate.

Table 8-18

EXHAUST SYSTEM SALES

	Exhaust System Products
Purchased New Products in Past 12 Months (Percentage of Total No. of Motorcycle Owners)	8.7%
Total Number of Buyers	616,000
Average Number of Exhaust System Products*	1.4
Total Exhaust System Products Purchased	862,000
Average Amount Spent per Purchase	$49.73
Total Dollar Volume	$30,633,000
Where Purchased**	
Dealer where motorcycle was purchased	22.2%
Other motorcycle dealer	41.3
Motorcycle accessory shop	25.0
Chain/department store	---
Discount auto center	1.0
Mail order	7.7
Other	1.0
Not stated	4.8

Source: Ziff-Davis Publications, "Motorcycle Aftermarket Survey", 1975.

* "Products" include any portion of a complete exhaust system; i.e. headers, mufflers, expansion chambers, etc.

** May add to more than 100% due to multiple answers.

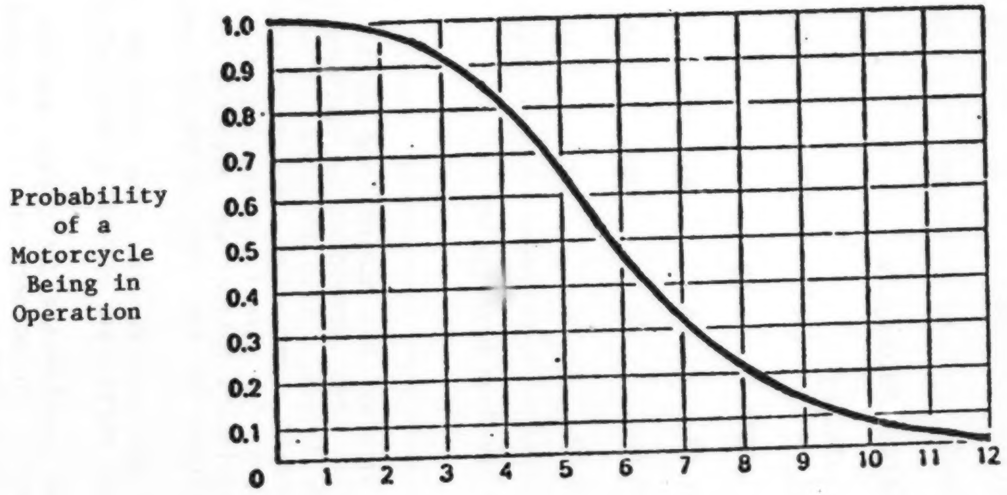
Table 8-19

FORECAST OF MOTORCYCLE EXHAUST SYSTEM PRODUCT SALES

Year	Motorcycle Stock	Exhaust System Unit Sales
1979	6705773	814080
1980	6919239	839995
1981	7339283	890988
1982	7847119	952640
1983	8381039	1017458
1984	9015023	1094423
1985	9728584	1181050
1986	10428851	1266062
1987	11081532	1345298
1988	11692021	1419411
1989	12227645	1484436
1990	12695499	1541233
1991	13105633	1591023
1992	13473094	1635633
1993	13811213	1676681
1994	14128853	1715242
1995	14434729	1752376
1996	14735735	1788918
1997	15036404	1825419
1998	15339588	1862226
1999	15647346	1899587
2000	15960715	1937630
2001	16224706	1969679
2002	16439736	1995783
2003	16605914	2015957
2004	16725635	2030492
2005	16806268	2040280
2006	16858094	2046572
2007	16890492	2050505
2008	16909154	2052771
2009	16918788	2053940
2010	16923084	2054462

Table 8-20

MOTORCYCLE SURVIVAL RATE[1]



Age(yrs)	Survival Rate
0.5	1.00
1.5	0.98
2.5	0.96
3.5	0.90
4.5	0.75
5.5	0.55
6.5	0.37
7.5	0.26
8.5	0.17
9.5	0.10
10.5	0.05
11.5	0.02
12.5	0.01

Source: 1. Yamaha's Comment on Emission Control Plan for New Motorcycles, Submitted to California Air Resources Board by Yamaha Motor Co., Ltd., Japan, April 1975.

Table 8-21

REGULATORY STUDY LEVELS

	Effective Date			
Regulatory Option	1981	1983	1986	1990
I-S*	83 dB			
II-S	83	80		
III-S	83	80	78	
IV-S	83	80	78	75

*Street Motorcycle

Regulatory Option	1981	1984	1987	1991
I-OR**	86 dB			
II-OR	86	82		
III-OR	86	82	80	
IV-OR	86	82	80	78

** Off-Road Motorcycles

Table 8-22 displays the nominal and worst case estimates for increases in annualized costs that correspond to purchase price increases expected at the various study levels. Also included are annalyized operation and maintenance cost incrases. The worst case estimates range up to $343 per motorcycle (1978 dollars) for street motorcycles at 78 dB. The cost stream for each of these regulatory options was assessed over a 30 year period (through 2010) to fully account for the costs of the ultimate level.

Ten percent was used for the time value of money. For each regulatory option, nominal and worst case estimates were calculated.

Operation and maintenance costs were applied to the existing motorcycle stock for each year. The motorcycles were assumed to have an average life of 6.1 years, after which they were retired.

8.4.2 Aftermarket Exhaust Annualized Costs

Aftermarket exhaust system prices as a result of noise regulation will increase due to two factors: (1) inexpensive non-complying systems

Table 8-22

TOTAL ANNUALIZED COSTS
(MILLIONS OF DOLLARS)*

Street Motorcycles

	Regulatory Level (dB J331a)			
Nominal (Expected) Case	83	80	78	75
Annualized Purchase Costs	10	56	150	237
Annualized O/M Costs	0	35	63	88
Total Annualized Costs	10	91	213	325
Worst Case				
Annualized Purchase Costs	11	109	241	299
Annualized O/M Costs	0	67	102	110
Total Annualized Costs	11	176	343	409

Off-Road Motorcycles with Engine Displacement Less than 170 cc

	Regulatory Level (dB J331a)			
Nominal (Expected) Case	86	82	80	78
Annualized Purchase Costs	0	.6	1.1	6.0
Annualized O/M Costs	0	0	1.3	5.6
Total Annualized Costs	0	.6	2.4	11.6
Worst Case				
Annualized Purchase Costs	0	.6	4.3	10.3
Annualized O/M Costs	0	.0	2.6	8.2
Total Annualized Costs	0	.6	6.9	18.5

Off-Road Motorcycles with Engine Displacement Greater than 170 cc

	Regulatory Level (dB J331a)			
Nominal (Expected) Case	86	82	80	78
Annualized Purchase Costs	0.9	3.1	10.7	14.9
Annualized O/M Costs	0	.6	2.6	3.4
Total Annualized Costs	0.9	3.7	13.3	18.3
Worst Case				
Annualized Purchase Costs	0.9	3.8	17.1	21.4
Annualized O/M Costs	0	1.3	3.8	4.6
Total Annualized Costs	0.9	5.1	20.9	26.0

---

* 1978 Dollars

will be eliminated, and (2) currently complying systems becoming more expensive since compliance to lower noise emission levels may require greater complexity. Total annualized costs will be calculated for this second factor only. It is reasonable to assume that the fractional increase in prices of currently complying aftermarket systems will parallel the fractional increase of OEM systems at the same level. Based on Table 7-27, the following increases for currently complying (i.e., those on the range of OEM noise levels) aftermarket exhaust systems are assumed:

	Regulatory Level (SAE J331a)			
	83 dB	80 dB	78 dB	75 dB
Fractional Increase in Price	10%	25%	50%	100%

To establish the current price of complying aftermarket systems, prices for current complying systems were compared to OEM replacement prices. While some systems for the popular models are less expensive than OEM replacements, others are up to $45 more expensive. This comparison is complicated by different exhaust system configurations and the presence or absence of header pipes. The OEM replacement price for large motorcycles exhaust systems varied between $100 and $250, with many such exhaust systems costing approximately $175. With replacement systems for smaller motorcycles factored in, $125 was used as the average current price of complying aftermarket systems.

Another factor necessary to compute annualized costs was the impact of regulation on demand for aftermarket exhaust systems.* Using price elasticity alone would be unrealistic because it does not account for performance and styling impacts. In addition, such factors would be applicable only for price increases in a narrow range, which was not expected for aftermarket systems. Based on discussions with aftermarket manufacturers, the following reductions in demand were estimated:

	Regulatory Level (SAE J331a)			
	83 dB	80 dB	78 dB	75 dB
Reduction in Demand	30%	40%	50%	60%

---

* Recall that the demand for aftermarket exhaust systems (for a specific noise standard) is a function of the stock of motorcycles complying with that standard. The stock of motorcycles is itself influenced, through price effects, by the motorcycle noise standards. The impact of an aftermarket exhaust system noise standard, however, is restricted to the price and demand impact on aftermarket sales for the (aftermarket baseline) motorcycle stock consistent with that specific noise standard.

The increase in purchase price and reduction in demand were combined to calculate total annualized costs:

	Regulatory Level (SAE J331a)			
	83 dB	80 dB	78 dB	75 dB
Aftermarket Exhaust Systems Total Annualized Costs ($M)	1.7	3.4	5.1	6.9

8.5 Impact on U.S. Employment Vehicle Manufacturers

Harley-Davidson and Kawasaki are the major motorcycle manufacturers with assembly facilities in the U.S. Assuming that these manufacturers will remain in the market at any regulatory level, their decrease in employment should follow the total market's decrease in demand. Based on elasticities developed from historical price-sales relationships, the following impacts on employment would be expected at each regulatory level: 83 dB--30 positions; 80 dB--160 positions; 78 dB-- 450 positions; 75 dB--1200 positions. However, if the noise standards prevent AMF/Harley Dividson from remaining in the market, its 3,300 motorcycle-related jobs in Milwaukee, Wisconsin and York, Pennsylvania would be affected.

Aftermarket Manufacturers

Total employment in the exhaust system manufacturing industry is expected to follow the impact on total demand for such systems. Some firms are expected to increase production, but a large number are expected to be forced out of the replacement exhaust system industry at any regulatory level. Using the same assumptions as in Section 8.4.2, the decrease in exhaust system manufacturing employment would be: 83 dB--375 positions; 80 dB--500 positions; 78 dB--665 positions; 75 dB--750 positions. Other aftermarket manufacturers (of apparel, insurance, etc.) are expected to suffer employment losses proportional to the change in the population of motorcycles. That population effect will increase over time until all existing motorcycles comply with the regulation. On average, the employment effect will be: 83 dB--20 positions; 90 dB--100 positions; 78 dB--250 positions; 75 dB--650 positions.

Distributors/Dealers

Employment among dealers and distributors is expected to decline in proportion to the decreased demand for vehicles and exhaust systems as a fraction of their total business. With the same assumptions for decreased demand, the decrease in dealer/distributor employment is expected to be: 83 dB--200 positions; 80 dB--1000 positions; 78- [illegible] positions; and 75 dB--7000 positions.

Total U.S. Employment Impact

Table 8-23 shows the total expected employment impact at each regulatory level. Although the levels assessed are for street motorcycles, complementary off-road regulations are also expected to contribute to the totals shown.

Table 8-23

EXPECTED U.S. EMPLOYMENT IMPACTS

	Regulatory Level (SAE J-331a)			
	83 dB	80 dB	78 dB	75 dB
Vehicle Manufacturers	30	160	450	1200
Aftermarket Exhaust System Manufacturers	375	500	625	750
Other Aftermarket Manufacturers	20	100	250	650
Dealers/Distributors	200	1000	2700	7000
Total	625	1760	4025	9600

8.6 Regional Impacts

The largest employment impacts are expected to occur at the dealer/distributor level. Except for a certain amount of concentration in California and other regions of high motorcycle interest, this impact is expected to be distributed evenly nationwide. The largest regional impact is expected to be in Southern California, where most of the aftermarket exhaust system manufacturers. Other regional impacts could occur in Milwaukee, Wisconsin, York, Pennsylvania, or Lincoln, Nebraska if Harley-Davidson withdrew from the market or if Kawasaki closed its U.S. assembly plant. In each of these regions, however, motorcycle related employment is a very small fraction of total area employment.

8.7 Impact on GNP and Inflation

Total annualized costs for the 78 dB regulatory level are less than $230 million annually. Since this figure constitutes considerably less than one-tenth of one percent of the U.S. economy, there is expected to be no sufficient impact on the U.S. Gross National Product nor on general inflation as a result of this regulation. Since motorcycles are primarily consumer oriented goods, price increases are not passed along in higher prices for other commodities, and no inflation multiplier applies.

8.8 Impact on Foreign Trade

The impact of any Federal motorcycle regulation on trade with Canada or Europe is expected to be negligible. Motorcycles do, however, account for a significant portion of total U.S. trade with Japan. In the peak sales year of 1973, the U.S. imported about 1.3 million motorcycles from Japan. At an average purchase price of about $1000 per motorcycle (1973 dollars) this represented about $1.3 billion in imports, almost 14 percent of the total $9.6 billion in goods imported from Japan in that year.

Clearly, any large impact on Japanese motorcycle revenues could affect this balance significantly. However, the price elasticities of demand associated with the forecasts of sales impacts as a result of the motorcycle noise regulations are approximately unity; hence the impact on Japanese motorcycle revenues is expected to be negligible. On this basis, the balance of trade with Japan is forecasted to be relatively unaffected by any motorcycle noise regulations.

8.9 Expected Impacts on Individual Manufacturers

8.9.1 Street Motorcycles

Honda Honda currently produces several motorcycle models that would meet an 80 dB (F-76a) regulatory level (GL-1000, CB-750F, CB-500T, CB-360T, XL-250). Honda is expected to have little difficulty bringing its entire model line into compliance with this level with no major model changes. Further reductions to the 78 dB regulatory level could be expected to be accomplished on most models with no major model changes. Based on EPA's motorcycle noise data base, the CB-550 would require the most attention. EPA expects that given sufficient lead time, Honda's expertise in motorcycle quieting would allow it to make the major model changes (including use of liquid cooling for some models) necessary to produce a limited number of motorcycle models at the 75 dB level. Based on current levels of the larger models, the CB-750F and CB-500T (no longer in production) appear to be candidates for achieving this regulatory level.

Yamaha Based on the current levels of Yamaha motorcycles, EPA expects that most models will comply to the 80 dB (F-76a) regulatory level without major model changes. The XS-750 indicates Yamaha's ability to produce large 4-stroke models with low mechanical noise. At the 78 dB regulatory level, several models may require major model changes including liquid cooling, depending on the mechanical noise contribution to the total vehicle noise. Even with extensive use of liquid cooling, Yamaha might have great difficulty in producing a large number of models at the 75 dB level.

Kawasaki Based on the current levels of Kawasaki motorcycles, most models would comply to the 80 dB (F-76a) level without major model changes. The most difficult model to quiet would be the KZ-900 motorcycle, its F-76a level is louder than average for a similar size motorcycle tested by the J-331a procedure. At the 78 dB regulatory level major model changes, including liquid cooling, may be necessary for the larger street motorcycles.

Even with extensive use of liquid cooling, Kawasaki might have great difficulty in producing a large number of models at the 75 dB level.

Suzuki Based on current levels of Suzuki motorcycles, most models would comply to the 80 dB (F-76a) regulatory level without major model changes. Suzuki motorcycle generally tested quieter than average for the F-76a test and the larger motorcycles are already near the 80 dB level (GT-750, GT-550, RE-5). Suzuki's recently introduced 4-stroke models incorporate many quieting features. At the 78 dB level, several models may need major model changes. The GT-750 and RE-5 already feature liquid cooling. Even with extensive use of liquid cooling, Suzuki may have great difficulty in producing a large number of models at the 75 dB level.

AMF/Harley-Davidson

(1) Large Models

Harley-Davidson motorcycles equipped with "California exhaust systems" meet the California 83 dB (SAE J331a) standard. It is apparent that current Harley-Davidson engines types would need major redesign to meet an 80 dB Federal standard. All known quieting techniques, perhaps including liquid cooling, may be necessary at this level. EPA believes that there is a reasonable chance that Harley-Davidson models may be able to achieve an 80 dB regulatory level without major redesign. Extended lead time may be an important factor in Harley-Davidson's ability to meet the 80 dB regulatory level.

It is clear, however, that levels below 80 dB are probably not achievable with the current engine types. Completely new engine designs will probably be necessary. Again, lead time for such effort would be a significant consideration.

It is clear from other manufacturers of large-bore twins, however, that the 75 dB level is essentiallly unachievable with these designs (see BMW, Moto Guzzi, Ducati). Considering Harley-Davidson's marketing position, it maybe impractical for them to switch engine types to the multi-cyclinder designs common to the Japanese manufacturers.

(2) Small Models

Based on current noise levels, the Harley-Davison 2-stroke models should be able to meet an 80 dB requirment without major model changes. Major model changes may be necessary at the 78 dB level and the 75 dB level may not be achievable.

BMW BMW motorcycles tested much quieter than average for the F-76a test and 80 dB is expected to be achievable with little change to current models. BMW felt that levels below 80 dB SAE J331a; 77-78 dB for F-76a for these motorcycles were unachievable with their large bore, and horizontally opposed twin cylinder engine.

Moto Guzzi, Ducati, Benelli, MV Agusta, Moto Morini These Italian manufacturers of large street motorcycles felt that 80 dB (SAE J331a; also estimated to be 80 dB on F-76a) was possibly achievable but at levels below 80 dB, the small fraction of their motorcycles produced for the U.S. would force them to consider withdrawing from the U.S. market.

Can-Am (Bombardier) Can-Am has produced versions of its high performance off-road and MX motorcycles as enduro models intended for limited street operation. Such enduro models would be subject both to EPA air emission and noise regulations applicalble to street motorcycles. The combined effect of these regulations could cause Can-Am to drop these models from the U.S. market if required to meet an 80 dB or lower level. Bombardier indicated that the high cost of labor and raw materials in Canada required continued production of high performance motorcycles in order to compete with the Japanese.

Bultaco Like Can-Am, Bultaco produces enduro versions of its high performance off-road and MX motorcycles as enduro models intended for limited street operation. Bultaco is currently struggling to meet the California 83 dB standard. Since demand for Bultaco enduro motorcycles are based on their off-road versions, major model changes such as liquid cooling are not feasible. The combined effect of air emission regulations and noise regulations could cause Bultaco to drop enduro models from the U.S. market at or below the 80 dB level.

Other Manufacturers Montesa, KTM, Carabela and other manufacturers also manufacture enduro models which have been street legal in some states. Since these manufacturers probably do not intend to meet air emission standards, they will be sold as strictly off-road motorcycles in the future.

8.9.2 Off-Road Motorcycles

Honda, Yamaha, Kawasaki, Suzuki All of the major Japanese manufacturers could use technology developed for their street and dual purpose motorcycles to meet an 86 dB level. Given sufficient lead time, all manufacturers are judged capable of 4-stroke conversion and mechanical treatment to achieve an 80 dB regulatory level for large off-road motorcycles and a 78 dB regulatory level for small off-road motorcycles. At these levels, however, performance impacts can be expected.

Other Manufacturers Husqvarna, Can-Am, Bultaco, OSSA, Montesa, KTM, Maico, CZ, Carabela, and several other manufacturers produce off-road and competition MX motorcycles. Almost all of the manufacturers consulted by EPA agreed that the 86 dB California standard was achievable at only a limited performance penalty. The manufacturers generally felt that 83 dB might be achievable at some time in the future, but that consumer shifts to higher performance competition models and user modifications to restore lost performance would make this effort fruitless. Since these manufacturers specialize in high performance, below the 86 dB level demand for their products would drop off significantly in comparison to the demand for lower priced Japanese models. Between 83 and 80 dB, most of these manufacturers would either drop out of the U.S. market or would market competition models only.

8.9.3 Aftermarket Exhaust Systems

Approximately half of the firms currently making replacement motorcycle exhaust systems will probably either go out of business or be forced to switch to alternate product lines as a result of Federal noise standards. These firms are typically small, low volume enterprises devoted exclusively to manufacturing motorcycle exhaust systems, with little or no capability for product design and development.

Other firms currently marketing replacement exhaust systems may likewise be forced to make major readjustments. Catalog suppliers such as J. C. Whitney, and other retailers who offer a wide range of automotive type products may be forced to find new suppliers, or to discontinue selling exhaust systems entirely. Some firms may resort to copying the designs of other manufacturers, a common practice at present.

The ten to twenty leading firms in the industry are expected to be able to produce complying systems, but at similar price and performance characteristics as OEM systems. Although total demand for aftermarket systems is expected to decline, these firms ought to at least preserve their unit volume as other manufacturers withdraw from the market. The twenty or thirty other firms that are expected to remain in the aftermarket muffler market are expected to experience severe difficulties in remaining competitive, with profits shrinking to the near break even point.

These expected impacts are based upon the assumption that the regulations will be effectively enforced at the State and local level to prohibit widespread sale and use of loud systems "designed" for motorcycles manufactured before the effective date of the Federal regulations or "competition" exhaust systems that can be easily modified by the operator for use on a regulated motorcycle.

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